Application of the Lower West Coast Surficial and Intermediate Aquifer Systems Model (LWCSIM) for the 2014 Reference Condition and 2040 Future Scenarios

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EXECUTIVE SUMMARY

Covering more than 5,100 square miles the Lower West Coast (LWC) Planning Area encompasses Lee County and portions of Collier, Hendry, Glades, Charlotte, and Monroe counties. The South Florida Water Management District is required to update the LWC Water Supply Plan every 5 years. During the water supply plan update process, demand projections are developed 20 years into the future by use type and water source. In 2014, an estimated 550 million gallons per day (mgd) of water were withdrawn from the surficial and intermediate aquifer systems (SAS and IAS) in the LWC Planning Area. SAS and IAS demands are projected to increase by approximately 100 mgd in 2040, predominantly in Lee and Collier counties.

The Lower West Coast Surficial and Intermediate Aquifer Systems Model (LWCSIM) was designed to evaluate the sustainability of existing and projected future LWC Planning Area demands from the SAS and IAS. The LWCSIM was used to identify areas where cumulative water use withdrawals may harm existing groundwater resources and natural systems (e.g., wetlands). The modeling effort also investigated the potential for increased risk of saltwater intrusion in the SAS and IAS. The results from the model simulations indicated that no widespread impacts are anticipated from groundwater withdrawals through 2040. However, the LWCSIM indicated a few localized areas may require continued monitoring, additional planning, and adaptive management strategies to prevent harmful impacts to groundwater resources and wetlands. The LWCSIM also indicated that groundwater withdrawals at the projected 2040 demand levels do not pose an increased risk of saltwater intrusion near major public supply wellfields in the coastal portions of the SAS and IAS.

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ACRONYMS AND ABBREVIATIONS

AFSIRS	Agricultural Field-Scale Irrigation Requirements Simulation
AG	Agriculture
CII	Commercial/Industrial/Institutional
DSS	Domestic Self-Supply
ET	evapotranspiration
FAS	Floridan aquifer system
FSAID	Florida Statewide Agricultural Irrigation Demand
IAS	intermediate aquifer system
L/R	Landscape/Recreational
LTA	Lower Tamiami aquifer
LWC	Lower West Coast
LWCSIM	Lower West Coast Surficial and Intermediate Aquifer Systems Model
MDL	maximum developable limit
mgd	million gallons per day
MHA	Mid-Hawthorn aquifer
PS	Public Supply
SAS	surficial aquifer system
SSA	Sandstone aquifer
SFWMD	South Florida Water Management District
TAZ	traffic analysis zone
WTA	Water Table aquifer

INTRODUCTION

The South Florida Water Management District (SFWMD) is required to update the water supply plans for each of the five planning areas within its jurisdictional boundaries every 5 years (**Figure 1**). Each regional water supply plan update estimates existing demands and projects demands at least 20 years into the future. The 2016-2020 cycle of regional water supply plan updates projected future demands through 2040. As part of the water supply plan update process, groundwater simulations are conducted to identify potential water supply or water resource issues that may occur during the planning horizon due to future pumping conditions.

The LWC Planning Area includes Lee County and portions of Collier, Hendry, Glades, Charlotte, and Monroe counties. The SFWMD developed the Lower West Coast Surficial and Intermediate Aquifer Systems Model (LWCSIM), which is a peer-reviewed, three-dimensional groundwater flow model based on the United States Geological Survey MODFLOW computer code (McDonald and Harbaugh 1988) to simulate SAS and IAS water levels based on withdrawals in the LWC Planning Area through 2040 (Bandara et al. 2020). The LWCSIM boundary extends from Charlotte County down the Gulf Coast to Everglades National Park in Monroe County, and from Lake Okeechobee in Glades County to the northwestern corner of Miami-Dade County. The model domain was divided into a uniform rectangular grid, oriented north-south, with uniform grid cell spacing of 1,000 feet.

In 2015, Geddes et al. (2015) completed a hydrostratigraphic analysis of the LWC Planning Area that updated the hydrogeologic framework used as the basis of the LWCSIM. The LWCSIM contains nine layers: five aquifers and four confining units (**Figure 2**). **Figure 3** shows cross-sections of the same transect in Collier County from Geddes et al. (2015) and from the LWCSIM, illustrating that the LWCSIM matches the hydrogeologic framework. The LWCSIM simulates the surficial and intermediate aquifer systems (SAS and IAS), but not the underlying Floridan aquifer system (FAS) as it is fully confined from the SAS/IAS. The Water Table aquifer (WTA) and Lower Tamiami aquifer (LTA) are the productive aquifers within the SAS, while the Sandstone aquifer (SSA) – clastic zone, SSA – carbonate zone, and Mid-Hawthorn aquifer (MHA) are the productive aquifers within the IAS. The LWCSIM domain, including model setup of rivers, canals, and wetlands, is shown in **Figure 4**. **Figure 5** shows the 2010 spatial distribution of urban, agriculture, wetland, and forest land use and land cover designations for the model domain. This information was used to spatially calculate recharge to the LWCSIM.

The LWCSIM was calibrated to both steady-state (average 1999 water levels) and transient conditions using groundwater levels, surface water levels, and surface water flows. The transient model was calibrated to the period from January 1999 through December 2012 and verified for the period from January 2013 through December 2014. Calibration is the process of adjusting model parameters within reasonable ranges to match measured heads as closely as possible over time. For the LWCSIM, verification involved checking the model's response to changing stresses (e.g., proposed wellfield demands) over the last 2 years of the transient model run.

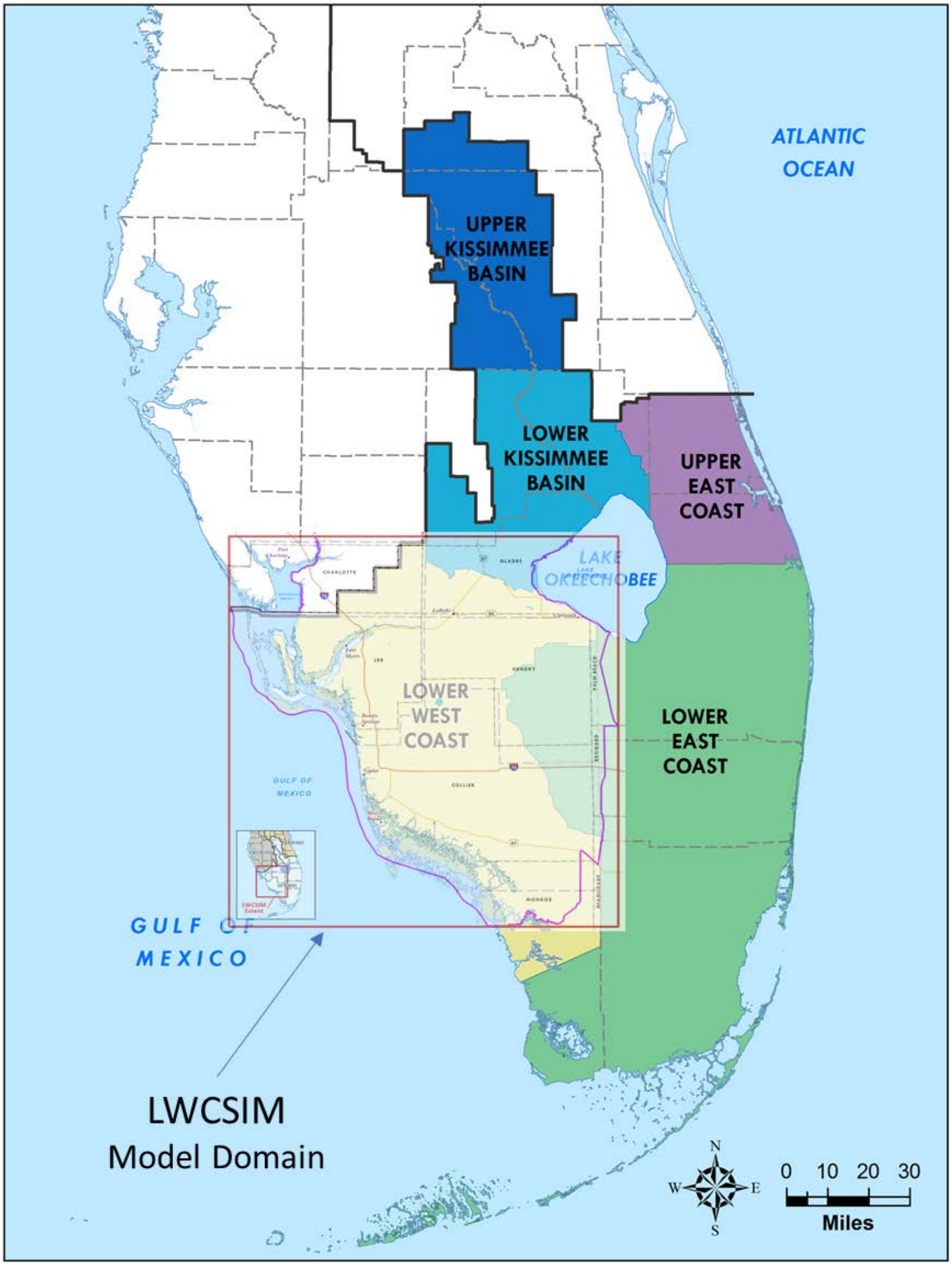

Figure 1. Location of the Lower West Coast Planning Area and the Lower West Coast Surficial and Intermediate Aquifer Systems Model (LWCSIM) domain.

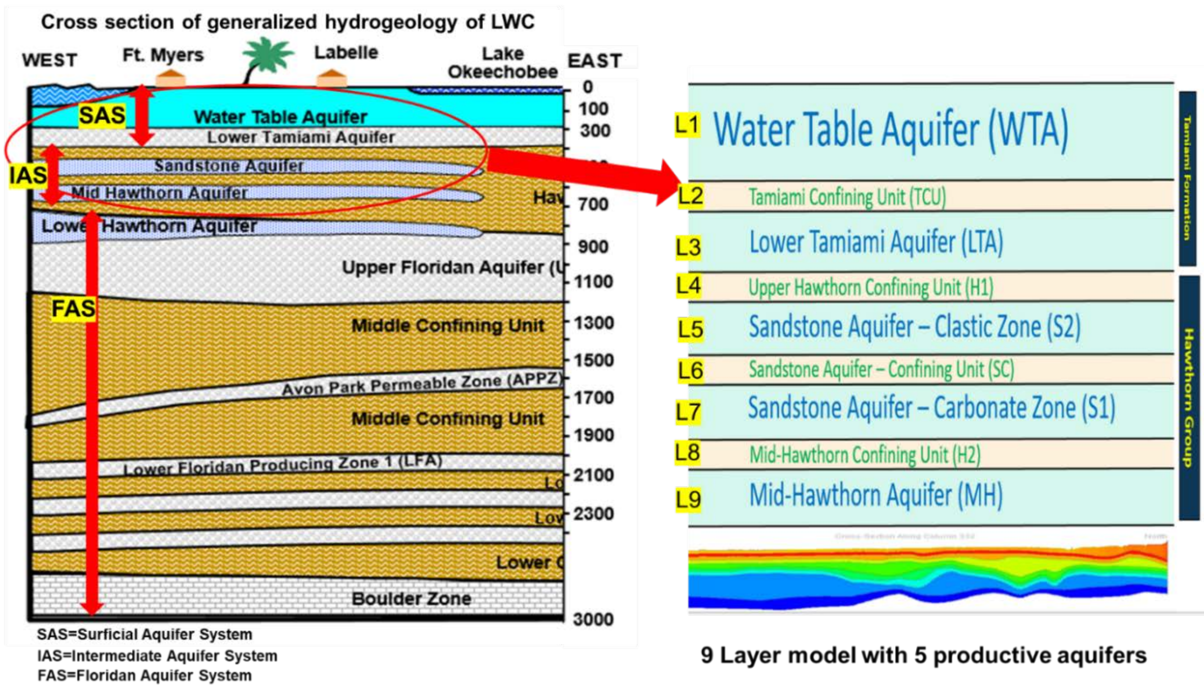

Figure 2. Model layers as based on updated hydrogeologic framework from Geddes et al. (2015).

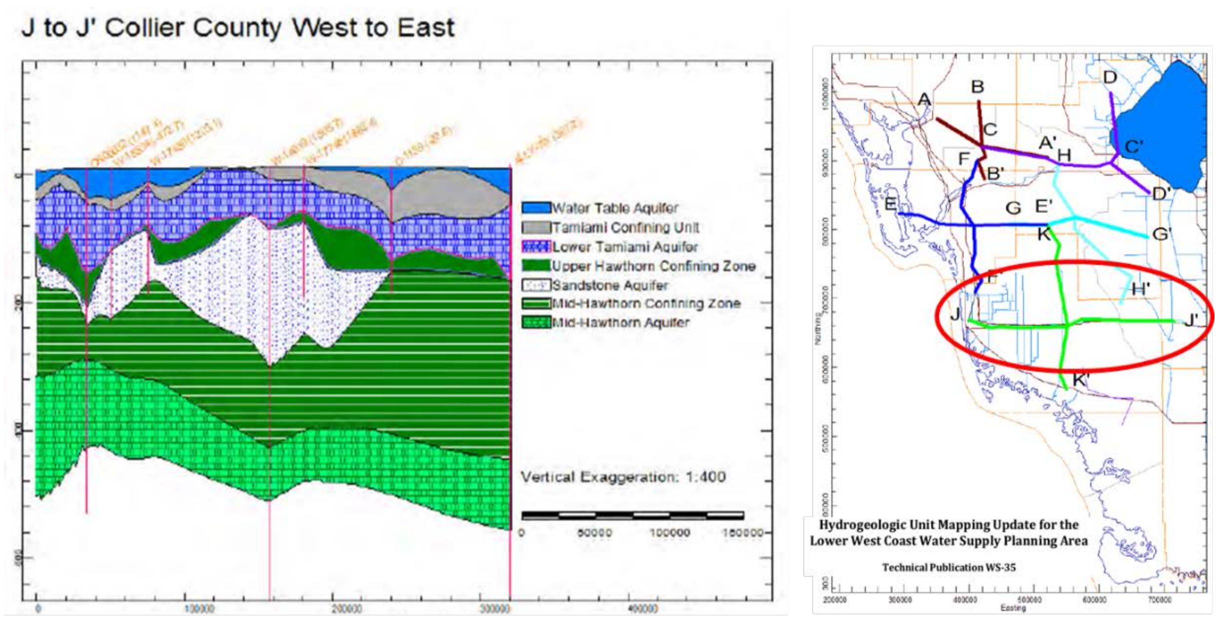

Figure 3. Cross-sections of hydrogeologic units in Collier County from (top) Geddes et al. (2015) and (bottom) the Lower West Coast Surficial and Intermediate Aquifer Systems Model (LWCSIM).

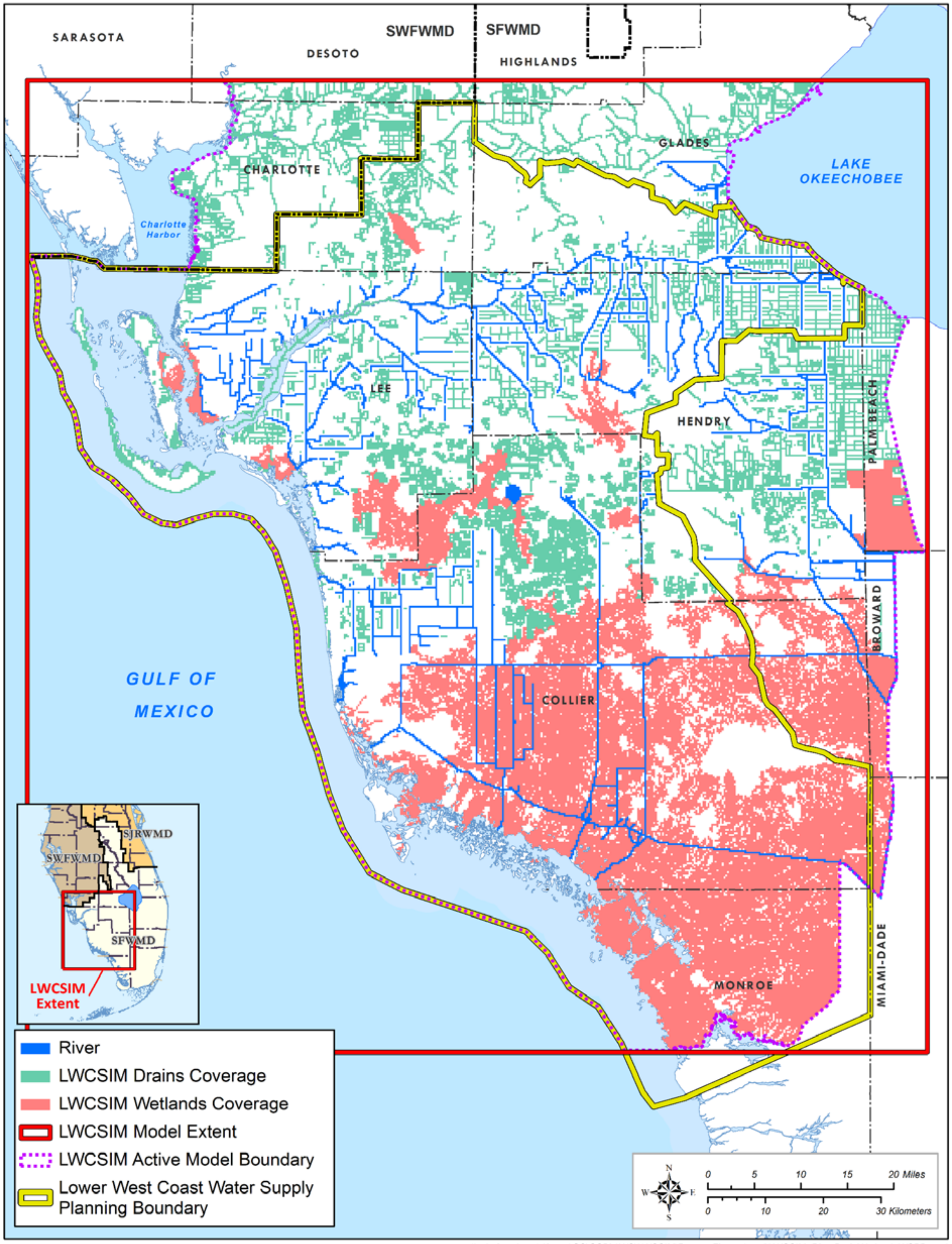

Figure 4. Model domain, including rivers, drains, and wetlands.

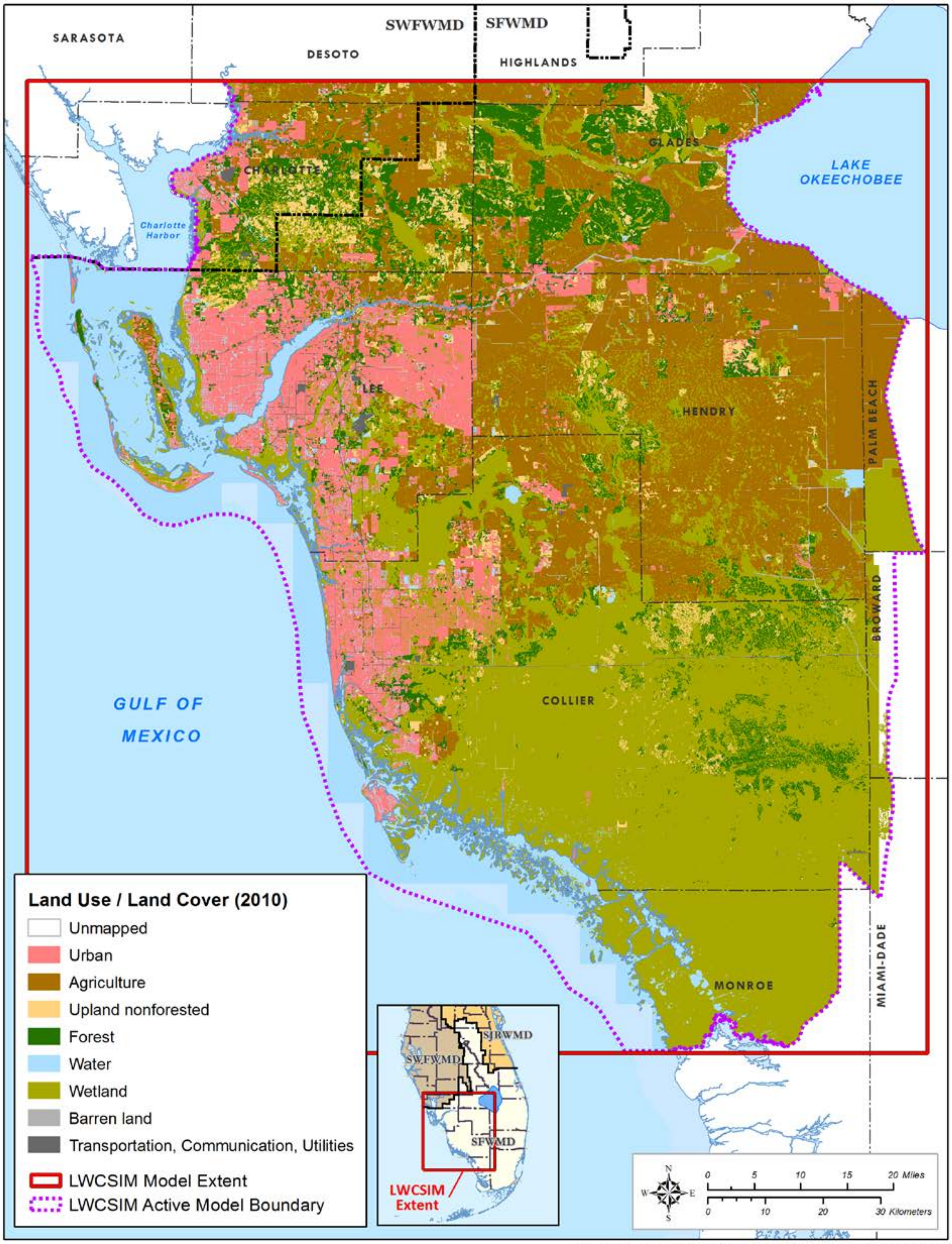

Figure 5. 2010 land use/land cover.

MODEL SCENARIOS

To evaluate potential changes within the LWCSIM boundary as a result of projected future groundwater withdrawals, two modeling scenarios were simulated: the 2014 reference condition scenario and the 2040 future scenario. Model simulations were conducted for 192 monthly stress periods (16 years) using historical climatic data from 1999 through 2014, which includes a wide range of climactic conditions to assess aquifer responses to varying demands. The climatic data (i.e., rainfall and evapotranspiration [ET]) were the same for the 2014 reference condition and 2040 future scenarios. The main difference between the scenarios was the amount and location of groundwater withdrawals. Due to changes in Public Supply (PS) and Domestic Self-Supply (DSS) well withdrawals, irrigation returns, ET, and the portion of recharge representing irrigation were adjusted.

The 2014 reference condition consisted of average pumping conditions from 2014, including monthly variations in demand, as taken from the calibrated 1999 to 2014 transient model. The yearly pumping conditions were repeated for 16 years, using 192 monthly stress periods of changing rainfall, ET, and recharge conditions.

The 2040 future scenario consisted of projected 2040 pumping demands from the *2017 LWC Water Supply Plan Update* (SFWMD 2017). Annual demands, including monthly variations, were repeated for 16 years, using 192 monthly stress periods of changing rainfall, ET, and recharge conditions, as taken from the calibrated transient model.

INPUT DATA SETS

Simulated SAS and IAS demands in the LWC Planning Area fall into six water use categories: Public Supply (PS), Agriculture (AG), Landscape/Recreational (L/R), Domestic Self-Supply (DSS), Commercial/Industrial/Institutional (CII), and Power Generation (PG). The LWCSIM did not consider Power Generation as a demand separate from CII, so it is not referred to in this report. The 2014 modeled PS demands were based on historical water use information collected by the SFWMD's Water Use Bureau. Proposed future pumping wells were added in the 2040 scenario based on locations provided by utilities. Well pumping ratios and monthly pumping distributions were based on 2014 historical data. The 2040 modeled PS demands were calculated from historical per capita use and projected population estimates by utility service area. If a utility also had FAS supply wells, demands were adjusted to reflect the SAS/IAS to FAS ratio. The SAS/IAS to FAS ratio is the ratio of water withdrawn from the SAS and/or IAS divided by the water withdrawn from the FAS for a given entity such as a PS utility. Additional growth in utility withdrawals above SAS/IAS permit allocation limits are assumed to come from the FAS. Monthly simulated pumpages were based on historical patterns to reflect changes in demands associated with seasonal variations in climate and population. The 2040 annual demands, with monthly variations, were repeated for the entire 16-year simulation period. Gradual annual increases from 2014 to 2040 were not simulated.

For AG, permit data were compared to information published by the Florida Department of Agriculture and Consumer Services (2017) in the Florida Statewide Agricultural Irrigation Demand (FSAID) report. The FSAID report contains estimated and projected agricultural acreage and water use demand throughout Florida. The Agricultural Field-Scale Irrigation Requirements Simulation (AFSIRS; Smajstrla 1990) model was run based on FSAID estimated and projected AG and L/R acreages to estimate irrigation demands for 2014 and 2040. Whenever there was an increase in projected demands, pumping was increased accordingly at existing wells within the permit area.

Monthly DSS demands were estimated based on county-wide average per capita use rates and projected population growth. For the 2040 scenario, SFWMD modelers and planners worked closely to place new DSS wells in areas of projected population expansion or to increase DSS pumping rates in existing DSS wells.

CII demands were minimal compared to the other water use categories and were simulated using permitted allocations.

Transient Model Data

The major stresses to the LWCSIM are boundary conditions related to rainfall, ET, recharge in the northern portion of the model, and wellfield withdrawals. The primary purpose of the LWCSIM is to address long-term (20 to 50 years) planning issues, where a longer simulation period can be used. A secondary application may include development of a companion tool for water use permitting purposes that requires a shorter simulation period and smaller grid cells in the area of interest. (The rectangular grid architecture and modular format of a MODFLOW groundwater flow model lends itself to development of such companion tools.) Considering the intended use of the LWCSIM and temporal data availability, especially withdrawal data, monthly stress periods were considered appropriate.

For this modeling effort, current and projected future changes in pumping were the primary considerations. The transient model was developed using monthly stresses and changes in stresses for January 1999 through December 2014 (192 monthly stress periods). Examples of model boundary conditions that change monthly include rainfall, recharge, ET (potential and groundwater ET), river stage, general head boundary stage, and well pumping. Therefore, most transient data used for calibration and verification, including rainfall, potential ET, river stages, and general head boundaries, were historical data. Changes in PS and DSS pumping resulted in changes to irrigation return flows. ET and recharge inputs were updated in each scenario to account for these changes in demand. Bandara et al. (2020) provides details regarding recharge, ET, river stage, and general head stage.

Simulated Water Use Demands – Pumping

Generally, demand growth occurs gradually over the simulation period; however, the simulated annual demands in 2040 were applied fully at the beginning of the simulation and repeated throughout the 16-year period (1999 through 2014). **Figure 6** shows the difference between how demands were applied in the LWCSIM and the normal gradual growth in demand over time. The simulated results can be considered conservative due to this approach. Note that the simulated annual demands contain monthly variability as a response to various factors such as climatic conditions. **Table 1** presents current and future projected water demands for each county in the LWCSIM, divided by well type, for the 2014 and 2040 scenarios. AG demands are the largest water use category within the LWCSIM domain. The largest AG demand is in Hendry County, which has no projected increase in demand for 2040. The largest projected AG demand increases are in Lee and Glades counties, with a projected 2040 increase of approximately 14 mgd each. Lee County has the largest L/R demands (51 mgd) and the largest projected increase in L/R demands (29.6 mgd). The largest PS demands (45 mgd) and the largest projected increase in PS demands are in Collier County. Reclaimed water use is limited to Lee and Collier counties. In the LWCSIM, reclaimed water is incorporated mainly as landscape irrigation return flows. Lee County has the largest reclaimed water use (39.7 mgd) and the largest projected increase in reclaimed water use (35.7 mgd). **Figures 7** and **8** show the monthly variability of demands in 2014 and 2040 for AG and all well types, respectively. **Figure 9** shows the areal distribution of pumping wells in the LWCSIM domain, colored according to aquifer.

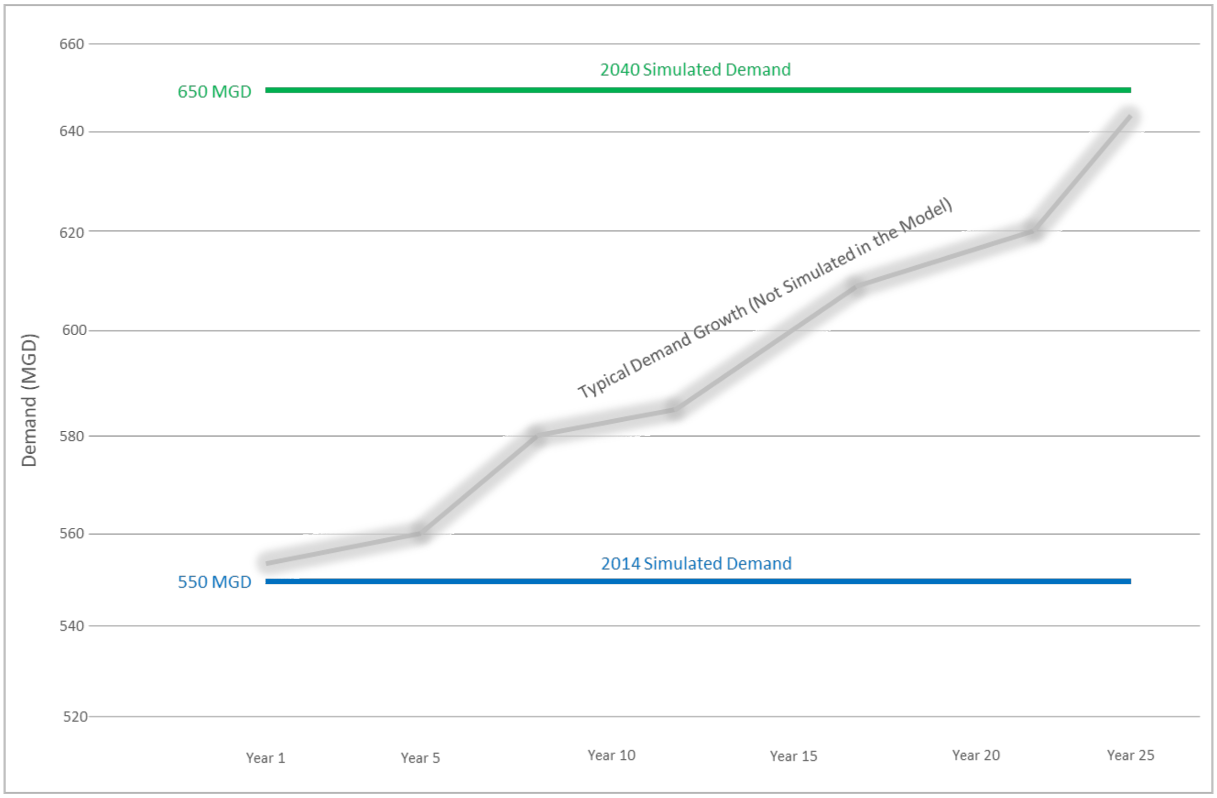

Figure 6. Typical and simulated demand growth in the Lower West Coast Planning Area.

Table 1. Water use summary, by county, within the Lower West Coast Planning Area.

County	2014 (mgd)	2040 (mgd)	Difference (mgd)
Agriculture			
Charlotte*	8.32	9.08	0.76
Collier	136.74	140.40	3.66
Glades*	6.97	20.80	13.83
Hendry	158.03	157.22	-0.81
Lee	34.09	48.06	13.97
Total	**344.15**	**375.56**	**31.41**
Landscape/Recreational			
Charlotte*	0.01	0.01	0.00
Collier	37.16	48.08	10.92
Glades*	0.25	0.76	0.51
Hendry	1.86	2.65	0.79
Lee	51.05	80.61	29.56
Total	**90.33**	**132.11**	**41.78**
Public Supply			
Charlotte*	0.10	0.88	0.78
Collier	45.15	56.17	11.02
Glades*	0.50	0.66	0.16
Hendry	0.90	0.55	-0.35
Lee	21.70	27.65	5.95
Total	**68.35**	**85.91**	**17.56**

County	2014 (mgd)	2040 (mgd)	Difference (mgd)
Domestic Self-Supply			
Charlotte*	0.05	0.07	0.02
Collier	4.41	6.91	2.50
Glades*	0.01	0.02	0.01
Hendry	0.04	0.05	0.01
Lee	36.97	47.59	10.62
Total	**41.48**	**54.64**	**13.16**
Reclaimed			
Collier	22.79	28.84	6.05
Lee	39.72	75.38	35.66
Total	**62.51**	**104.22**	**41.71**

mgd = million gallons per day.
* Numbers for Charlotte and Glades counties reflect only what is contained within the active model domain.

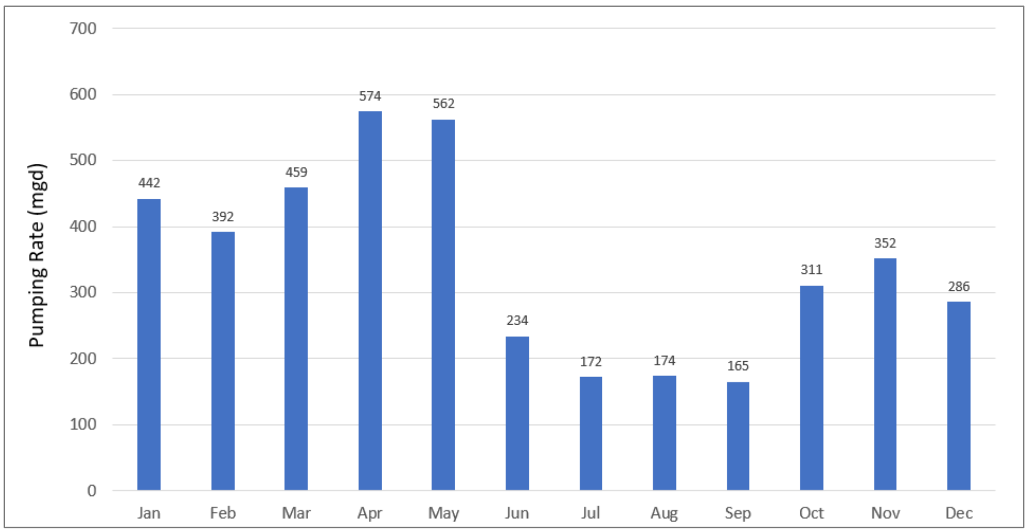

Figure 7. Monthly Agriculture water demand (mgd) variability – 2014 and 2040.

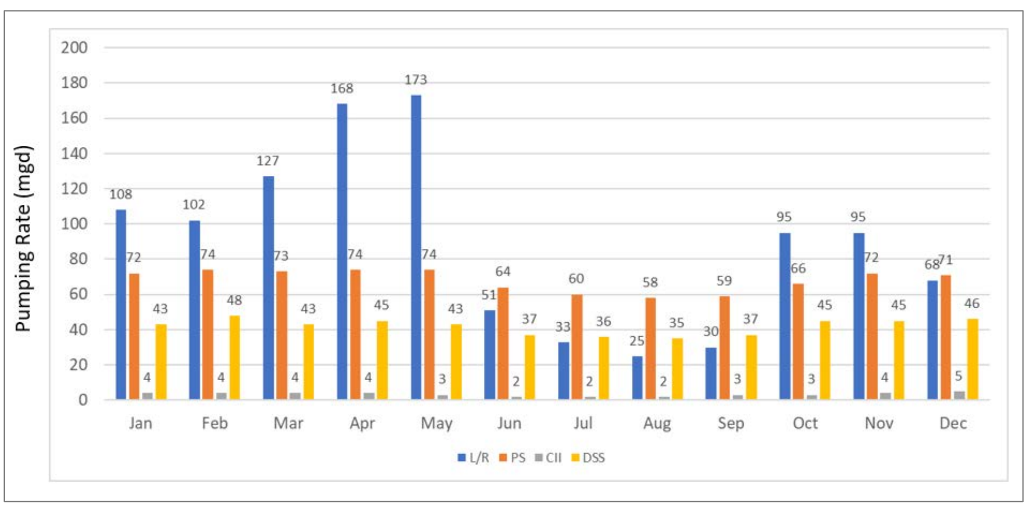

Figure 8. Monthly Commercial/Industrial/Institutional, Domestic Self-Supply, Public Supply, and Landscape/Recreational water demand (mgd) variability – 2014 and 2040.

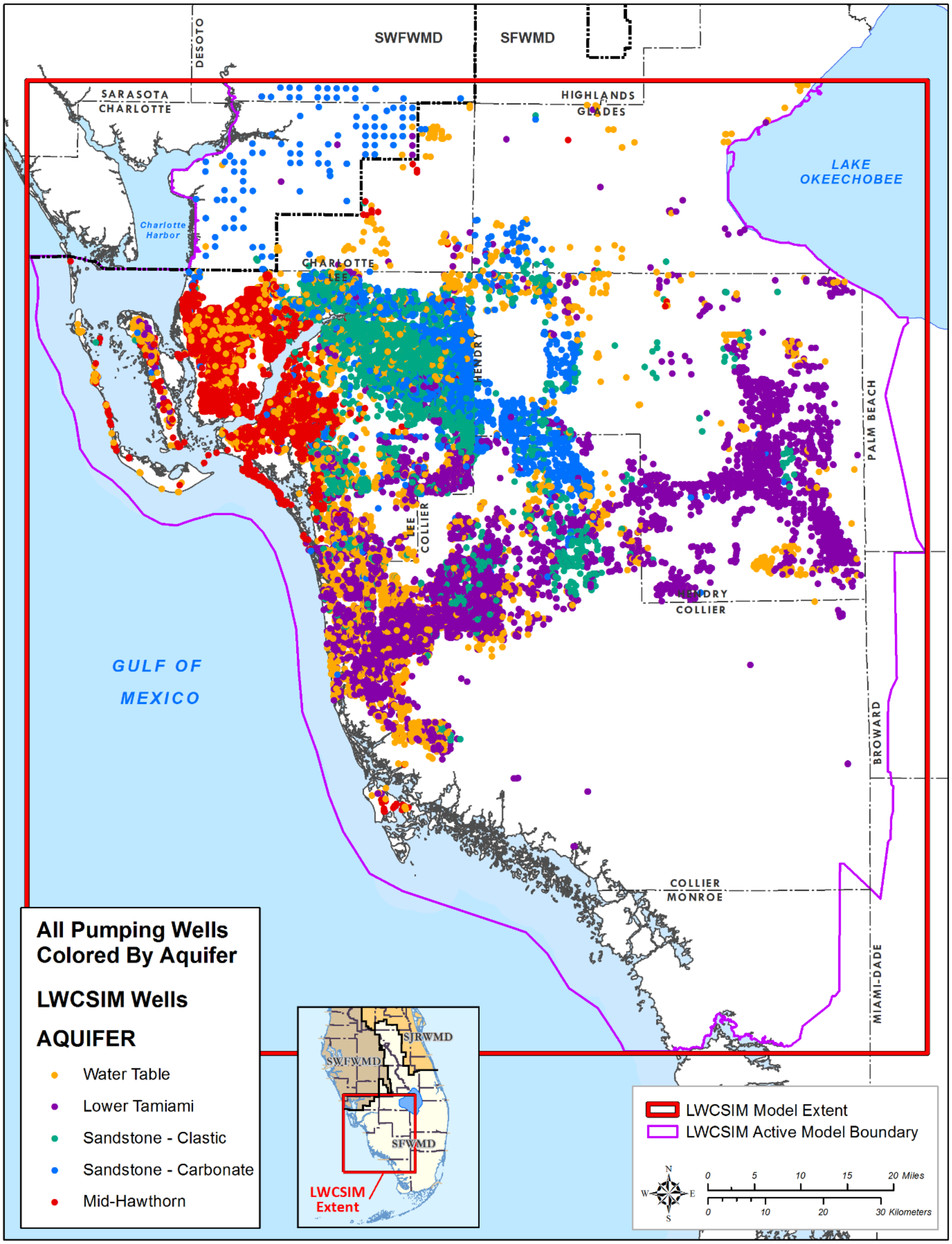

Figure 9. Pumping wells in the model domain, by aquifer.

Agriculture and Landscape/Recreational Pumping

AG and L/R represent the largest water users in the LWC Planning Area (**Table 1**). AG includes water use classifications for agriculture, diversion and impoundment, aquaculture, livestock, and nursery. The predominant AG crops in the LWC Planning Area are citrus, sugar cane, improved pasture, and various vegetable crops (e.g., beans, tomatoes, melons, other row crops). Groundwater withdrawals for AG mainly occur inland in north-central Collier, eastern Lee, Hendry, and Glades counties. Some AG demands are met with surface water (e.g., Caloosahatchee River). **Figure 10** presents the major AG permits within the LWCSIM domain.

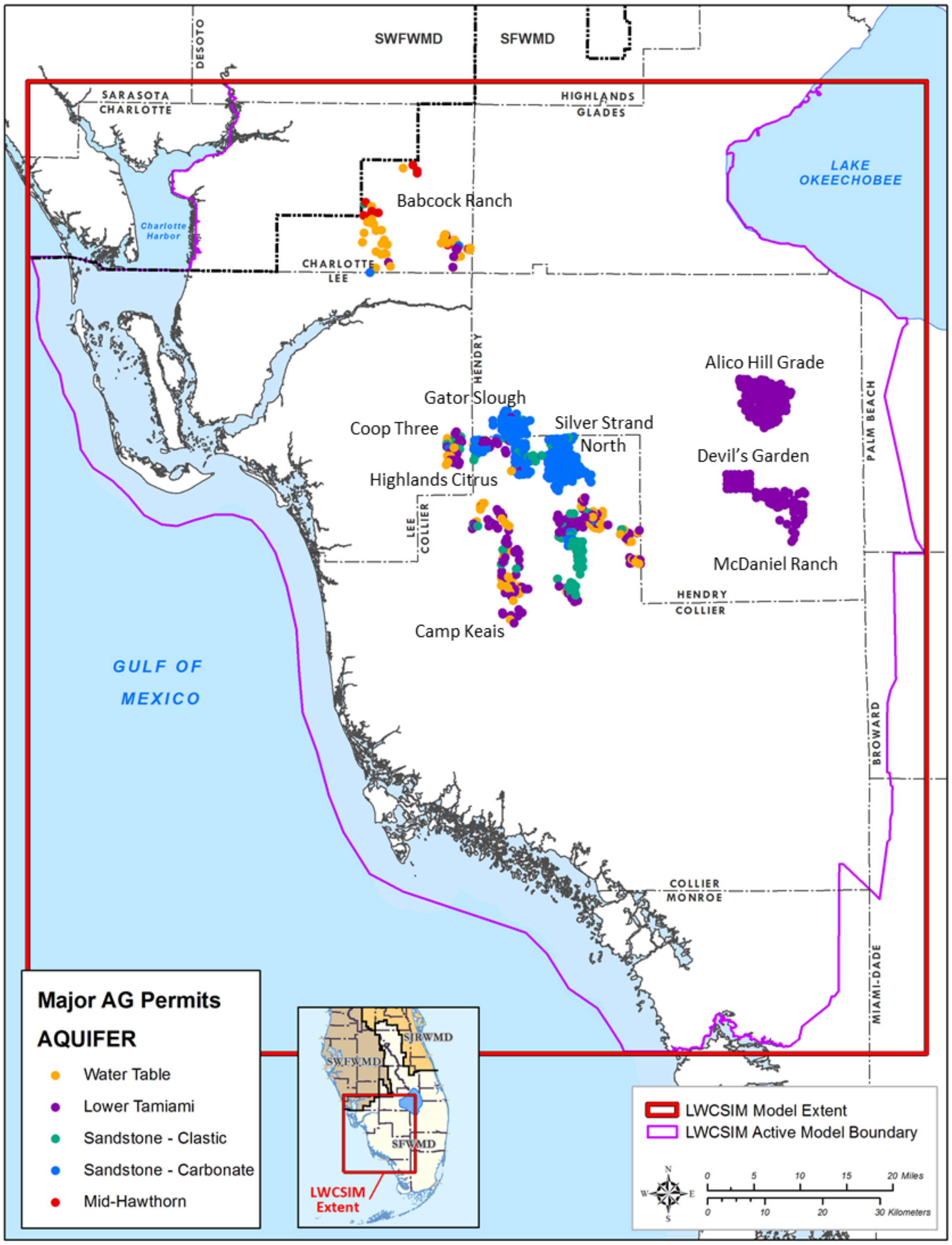

Figure 10. Major Agriculture permits in the model domain, by aquifer.

Within the LWCSIM domain, there are 4,504 AG water use permits and 11,563 associated facilities spread throughout Lee, Collier, Hendry, Glades, and Charlotte counties, with most permittees and facilities located within Lee, Collier, and Hendry counties. **Table 2** presents the current permitted allocations and current and future demands of the major AG permits shown in **Figure 10**. No significant increases in projected AG demands are seen in the LWC Planning Area; however, some increases in eastern Hendry County (within the Lower East Coast Planning Area) are projected. Additionally, there is a significant decrease in AG demand (more than 15 mgd) due to the loss of AG wells resulting from the acquisition of U.S. Sugar Corp. lands in the C-139 Annex in southeastern Hendry County (within the Lower East Coast Planning Area). In general, AG demands throughout the LWC Planning Area show only a slight projected increase of 9% (32 mgd) throughout the planning period.

Table 2. Current permitted allocations and the current (2014) and future (2040) demands of major Agriculture permits.

Permit No.	Permittee	Allocation (mgd)	Total 2014 (mgd)	Total 2040 (mgd)	Difference (mgd)
Charlotte					
08-00002-W	Babcock Ranch	8.91	8.07	8.76	0.69
Collier					
11-00128-W	Corkscrew Citrus	13.78	12.06	9.33	-2.73
11-00236-W	Silver Strand III	8.05	5.07	4.12	-0.95
11-00628-W	Ranch One Coop	9.36	7.30	8.01	0.71
11-00233-W	Silver Strand North	11.48	11.06	10.38	-0.68
11-00094-W	Highlands Citrus	7.70	4.32	3.74	-0.58
11-00321-W	Harker Farms	12.16	10.88	10.35	-0.53
11-00262-W	Gator Slough	16.25	13.65	14.17	0.52
11-00112-W	Shaggy Cypress	13.43	5.40	4.92	-0.48
11-00111-W	Silver Strand IV	6.06	6.00	5.65	-0.35
11-00113-W	Hogan Island	10.52	5.09	5.43	0.34
11-00106-W	Camp Keais Ag Dev	16.63	5.60	5.32	-0.28
11-00363-W	Gopher Ridge Citrus	10.35	6.89	6.89	0.00
Hendry					
26-00094-W	US Sugar Corp	32.00	21.68	0.00	-21.68
26-00453-W	Alico Hill Grade Combine	10.45	5.25	5.63	0.38
26-00087-W	McDaniel Ranch	28.25	22.60	22.83	0.23
26-00073-W	Devil's Garden South	7.64	6.01	6.07	0.06
Lee					
36-00167-W	Cooperative Three Inc.	7.54	1.81	1.69	-0.12

mgd = million gallons per day.

Most L/R withdrawals (including those for golf courses and landscape irrigation) occur in Lee and Collier counties, with the largest projected 2040 increase of nearly 30 mgd occurring in Lee County. L/R demands in Hendry County are projected to increase 0.79 mgd in 2040. L/R demands in Glades County are projected to increase 0.51 mgd in 2040. No change is projected in Charlotte County (**Table 1**).

Public Supply Pumping

Within the LWCSIM domain, there are 32 PS water use permits and 509 associated facilities spread throughout Charlotte, Glades, Lee, Collier, and Hendry counties, with most facilities located within Lee and Collier counties. **Figure 11** presents the major PS permitted wellfields within the LWCSIM. Historical PS withdrawal records generally are available throughout the planning area and for the calibration period as monthly pumped raw water volumes reported by utilities to the SFWMD's Water Use Bureau.

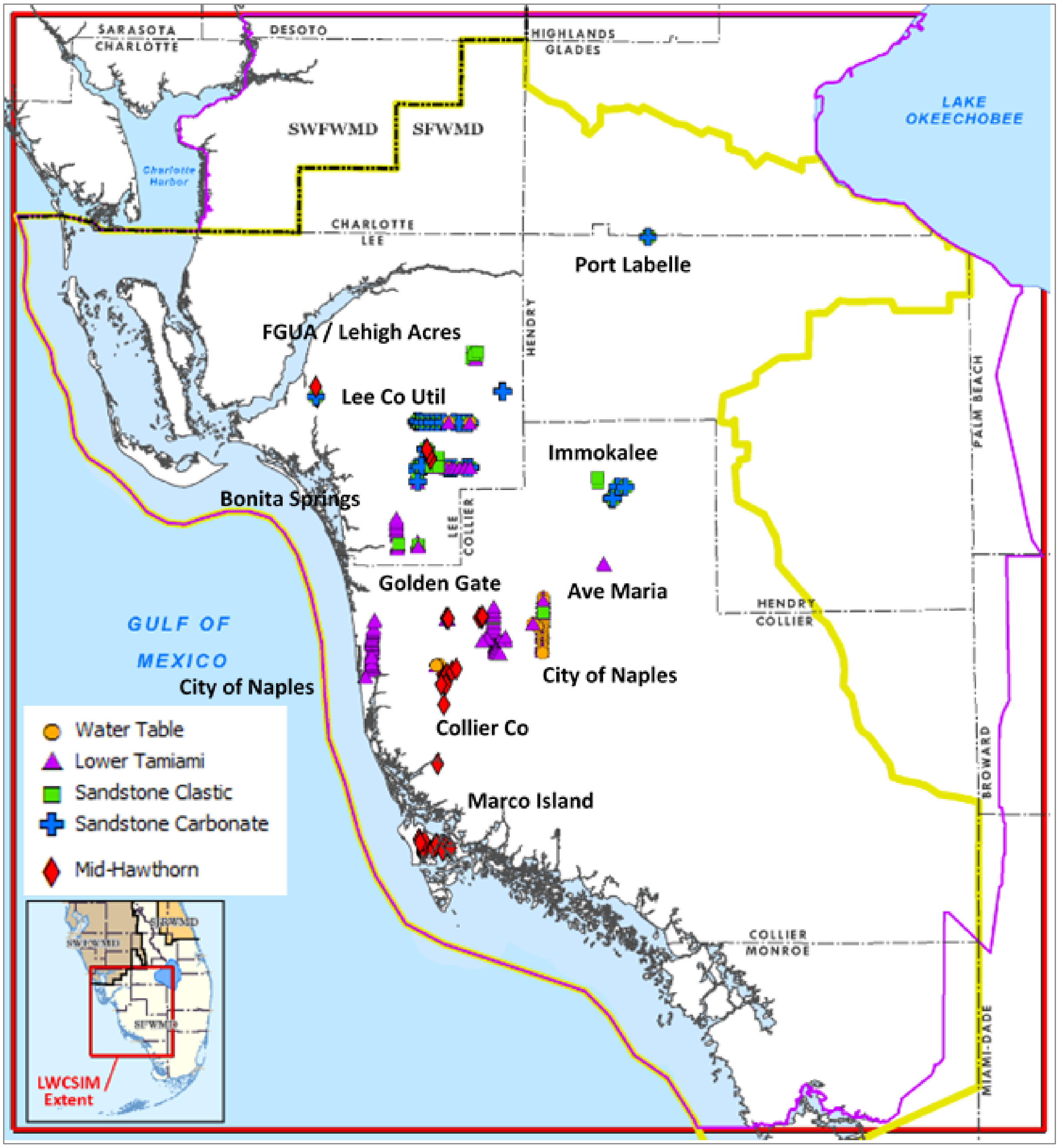

Figure 11. Major Public Supply permits within the model domain.

Withdrawal rates of production wells open to multiple aquifers were apportioned among the productive layers (excluding confining units) based on the transmissivities of open intervals within the aquifers. PS well withdrawals for 2014 and 2040 were simulated based on annual estimated and projected demands from the 2017 LWC Water Supply Plan Update (SFWMD 2017). Annual demands were divided by well proportionate to the well diameter. Annual demands were divided by aquifer based on the open interval of the well and model layering information. **Table 3** presents current and future projected demands for some of the major PS permits shown in **Figure 11**. The **Appendix** contains a table of all PS permits in the LWCSIM domain and their average 2014 and 2040 demands. The biggest projected increase (approximately 6 mgd) is associated with the City of Naples WTA wellfield. The Golden Gate LTA wellfield has a projected demand increase of approximately 2 mgd, and the Bonita Springs LTA wellfield has a projected demand increase of 1.95 mgd.

Table 3. Current and projected future major Public Supply permit demands.

Permit No.	Permittee	Aquifer	Annual Allocation (mgd)	2014 (mgd)	2040 (mgd)	Difference (mgd)
11-00017-W	City of Naples	Lower Tamiami	6.00	3.75	3.78	0.03
		Water Table	16.80	10.38	16.44	6.06
11-00148-W	Florida Governmental Utility Authority	Water Table	2.49	1.64	0.00	-1.64
11-00249-W	Golden Gate	Lower Tamiami	26.50	16.06	16.80	0.74
		Mid-Hawthorn	16.00	7.71	9.00	1.29
36-00003-W	Lee County Utilities	Sandstone	10.61	8.45	9.24	0.79
		Lower Tamiami	4.61	2.80	4.00	1.20
		Water Table	3.23	2.48	3.00	0.52
36-00008-W	Bonita Springs	Lower Tamiami	5.74	3.53	5.48	1.95

mgd = million gallons per day.

Domestic Self-Supply Pumping

DSS wells represent nearly 10% of the total water demand in the LWCSIM. Total DSS demand was 41 mgd in 2014 and projected to be 55 mgd in 2040. The projected increase in DSS demand occurs primarily in Lehigh Acres in eastern Lee County (**Table 4**). Monthly DSS demands were estimated based on county average per capita use rates and projected population growth. For the 2040 future scenario, SFWMD modelers and planners worked closely to place new DSS wells in areas of projected population expansion. This was accomplished using traffic analysis zone (TAZ) shapefiles in combination with areas of known and projected population growth. A detailed explanation of how TAZ shapefiles were developed and used with 2040 population and demand projections can be found in Appendix B of the 2017 LWC Water Supply Plan Update (SFWMD 2017). Areas such as Lehigh Acres in eastern Lee County are experiencing rapid population growth, so a large number of new DSS wells were added in that area for the 2040 future simulation.

Table 4. Domestic Self-Supply demand, by county.

County	2014 Average (mgd)	2040 Average (mgd)	Difference (mgd)
Charlotte*	0.05	0.07	0.02
Collier	4.41	6.91	2.50
Glades*	0.01	0.02	0.01
Hendry	0.04	0.05	0.01
Lee	36.97	47.59	10.62
Total	**41.49**	**54.63**	**13.14**

mgd = million gallons per day.
*Numbers for Charlotte and Glades counties reflect only what is contained within the active model domain.

MODEL SCENARIO RESULTS

The simulation results are presented as changes to average water levels and changes in average horizontal and vertical groundwater flow direction (using velocity vectors) between 2014 and 2040. The results show that, in places, water levels are predicted to decline due to projected increases in pumping and rebound due to projected decreases in pumping or removal of pumps. Groundwater velocity vectors, which change in direction and magnitude (size) in response to increases or decreases in pumping, are useful for saline intrusion analyses. Regional changes in water levels in wetland areas due to well withdrawals were explored by comparing the 2014 reference condition and 2040 future scenarios with a scenario in which all pumps and return flows were turned off.

The LWCSIM was used to examine the maximum developable limits (MDLs) in the LTA, SSA, and MHA under 2014 conditions only. MDLs are SFWMD regulatory criteria as part of the LWC Aquifers Minimum Flow and Minimum Water Level (MFL) prevention strategy (Chapter 40E-8, Florida Administrative Code).

Discussion of Groundwater Level Variations

Figures 12, **14**, **16**, **18**, and **20** present side-by-side views of the mean potentiometric heads (average head for the 192 stress periods simulation) in the five aquifers for 2014 and 2040. The potentiometric head difference between the 2040 future pumping condition and 2014 reference pumping condition are shown in **Figures 13**, **15**, **17**, **19**, and **21**. In other words, the figures show additional drawdowns or rebounds of the potentiometric surface of each aquifer due to increased or decreased withdrawals. Shades of orange to red represent additional drawdowns (i.e., decreasing water levels) while shades of yellow to blue represent additional rebounds (i.e., increasing water levels). Areas where the aquifer is thin or absent are shown in gray.

In **Figures 13**, **15**, **17**, and **19**, representing the WTA, LTA, SSA-clastic, and SSA-carbonate, respectively, slight drawdowns (0.5 to 3 feet) can be seen in areas that correspond to changing AG demands (western Lee and Hendry counties) and projected population growth resulting in DSS well increases in Lehigh Acres (western Lee County). In **Figures 17** and **19**, the increase in drawdown in SSA-clastic and SSA-carbonate, respectively, in Charlotte County is associated with the projected increase in water withdrawals associated with the Babcock Ranch community development as well as a projected increase in AG demands of 0.69 mgd (**Table 2**). The water level rebound around Cape Coral is the result of a decrease in DSS well use in the MHA and the associated future expansion of PS utilities using the FAS, as well as increasing irrigation return flow from PS. This is especially clear in **Figure 21**, where the predicted rebound is projected to be greater than 25 feet in the MHA due to DSS wells being taken offline between 2014 and 2040. The MHA generally is not very productive; therefore, the aquifer response to pumping changes generally is high. Other notable drawdowns occur in the WTA and LTA at the intersection of Lee, Collier, and Hendry counties (**Figures 13** and **15**, respectively), where the LTA and SSA are thinner (approximately 20 feet) and less productive.

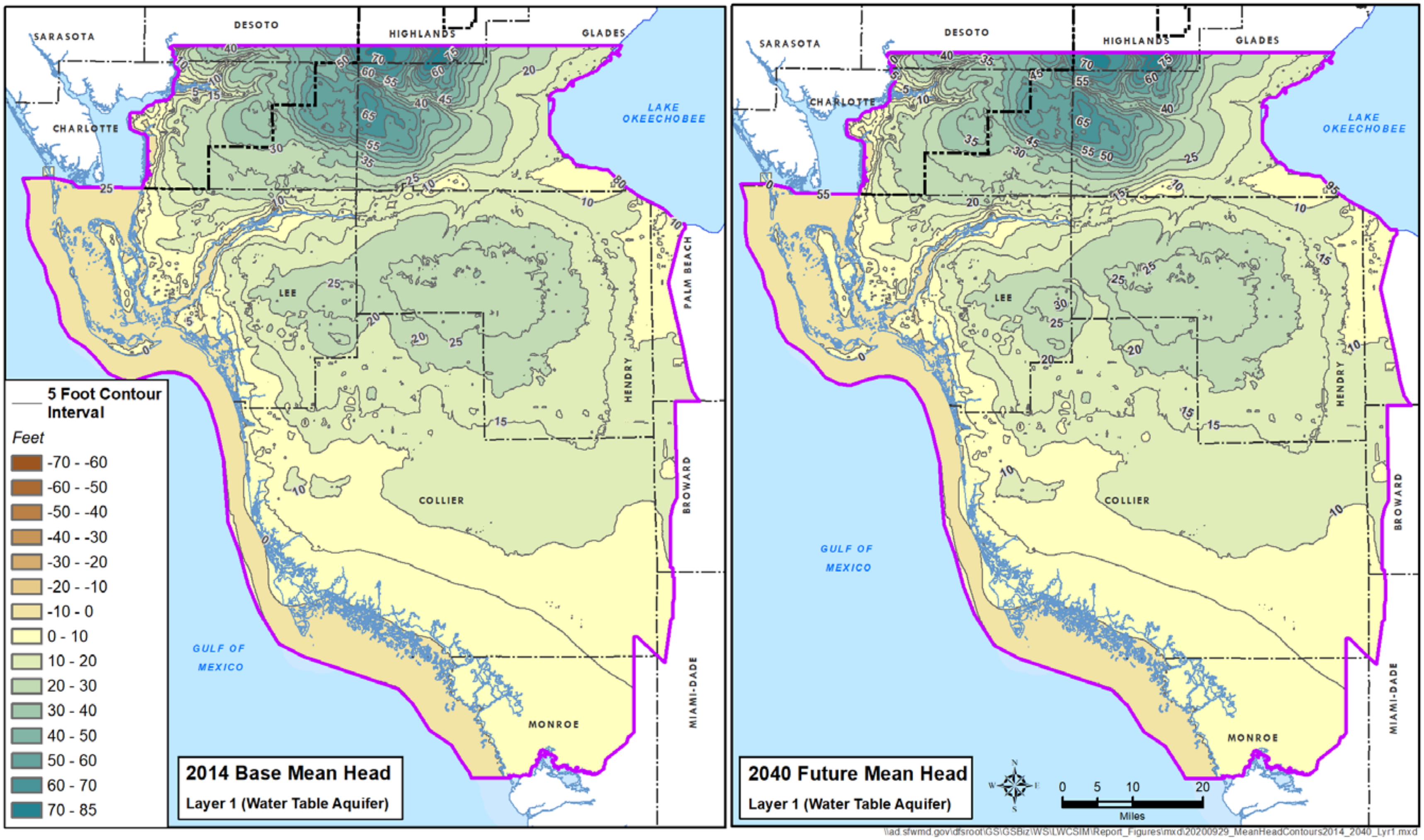

Figure 12. 2014 and 2040 mean heads in the Water Table aquifer.

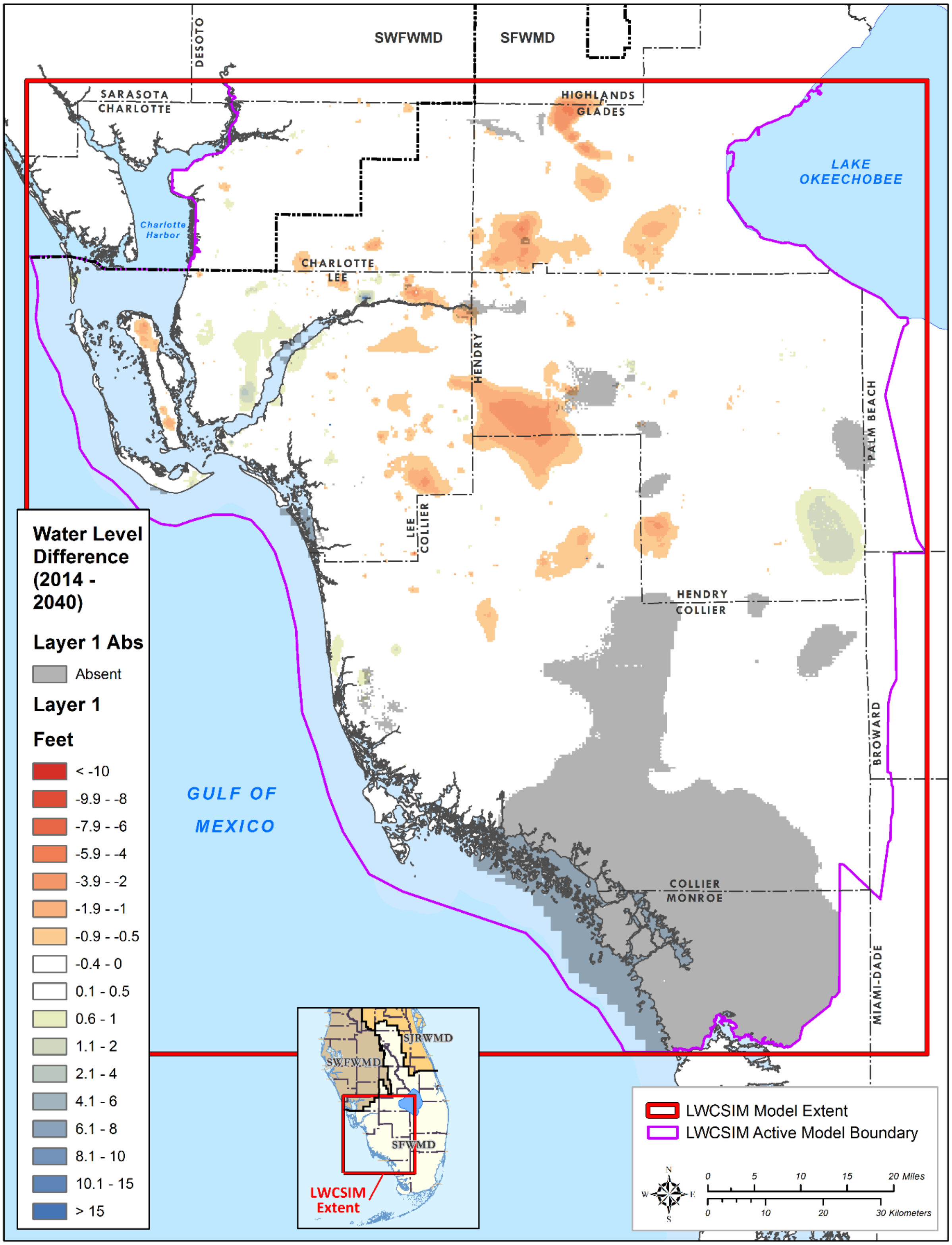

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Figure 13. 2014 to 2040 water level difference in the Water Table aquifer.

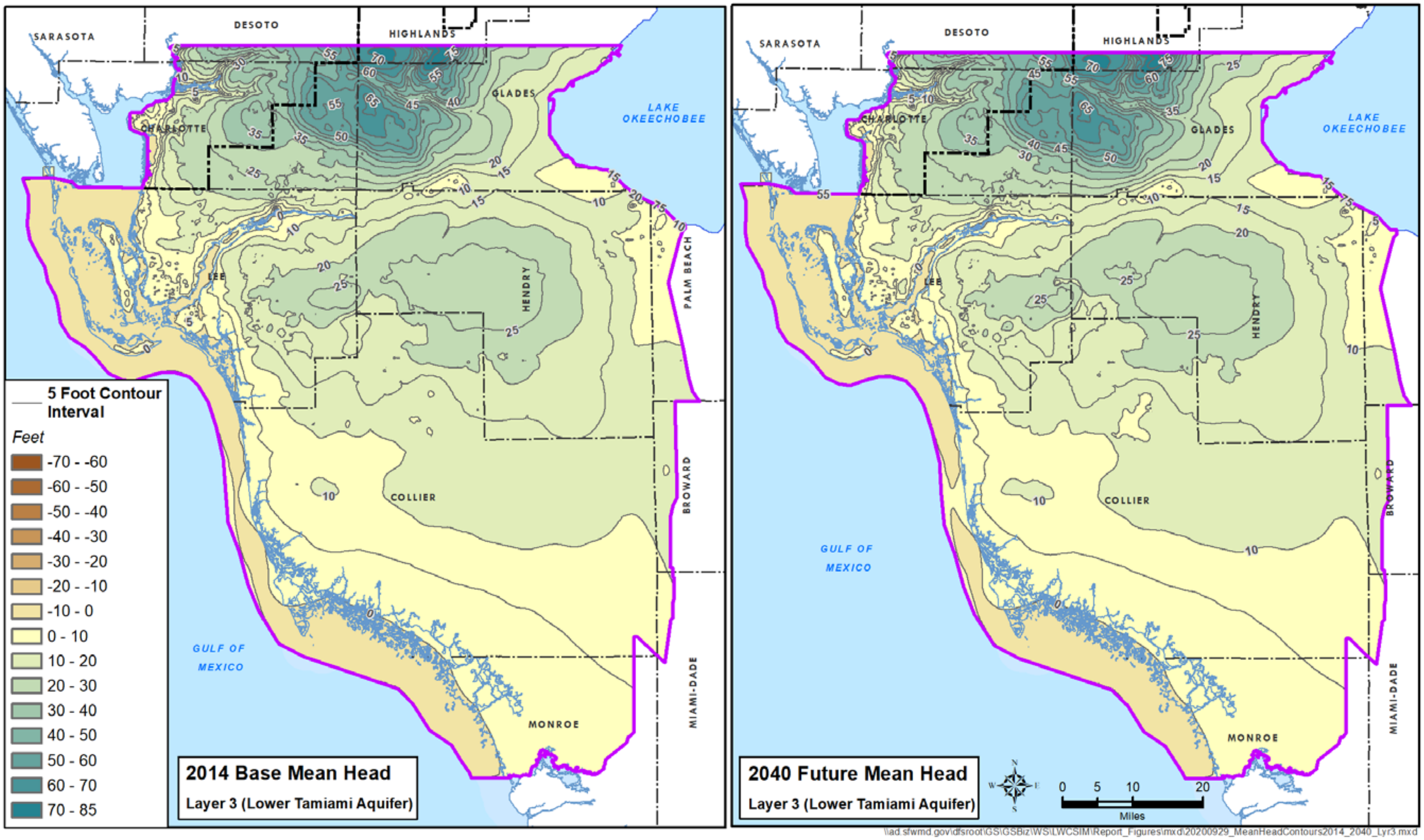

Figure 14. 2014 and 2040 mean heads in the Lower Tamiami aquifer.

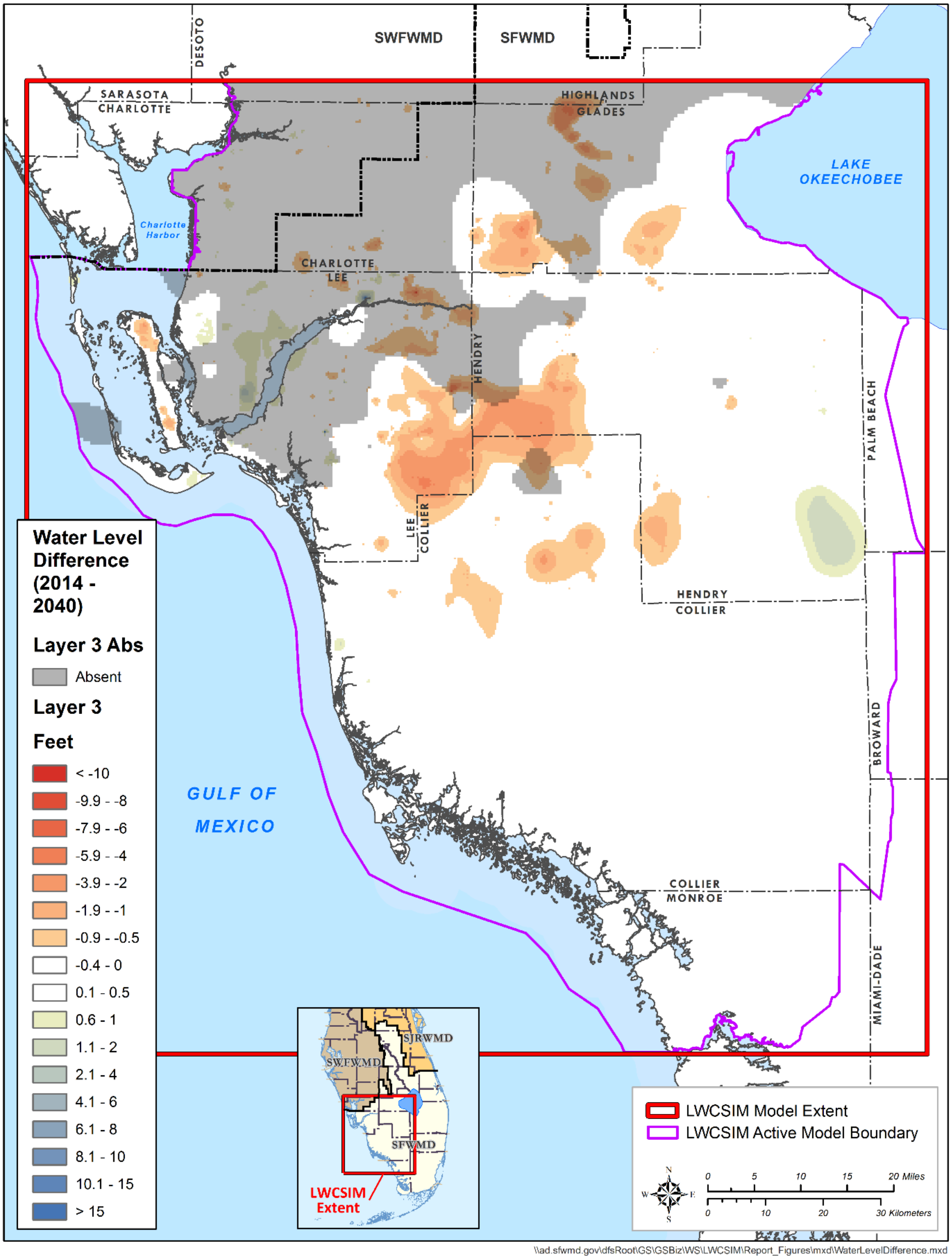

Figure 15. 2014 to 2040 water level difference in the Lower Tamiami aquifer.

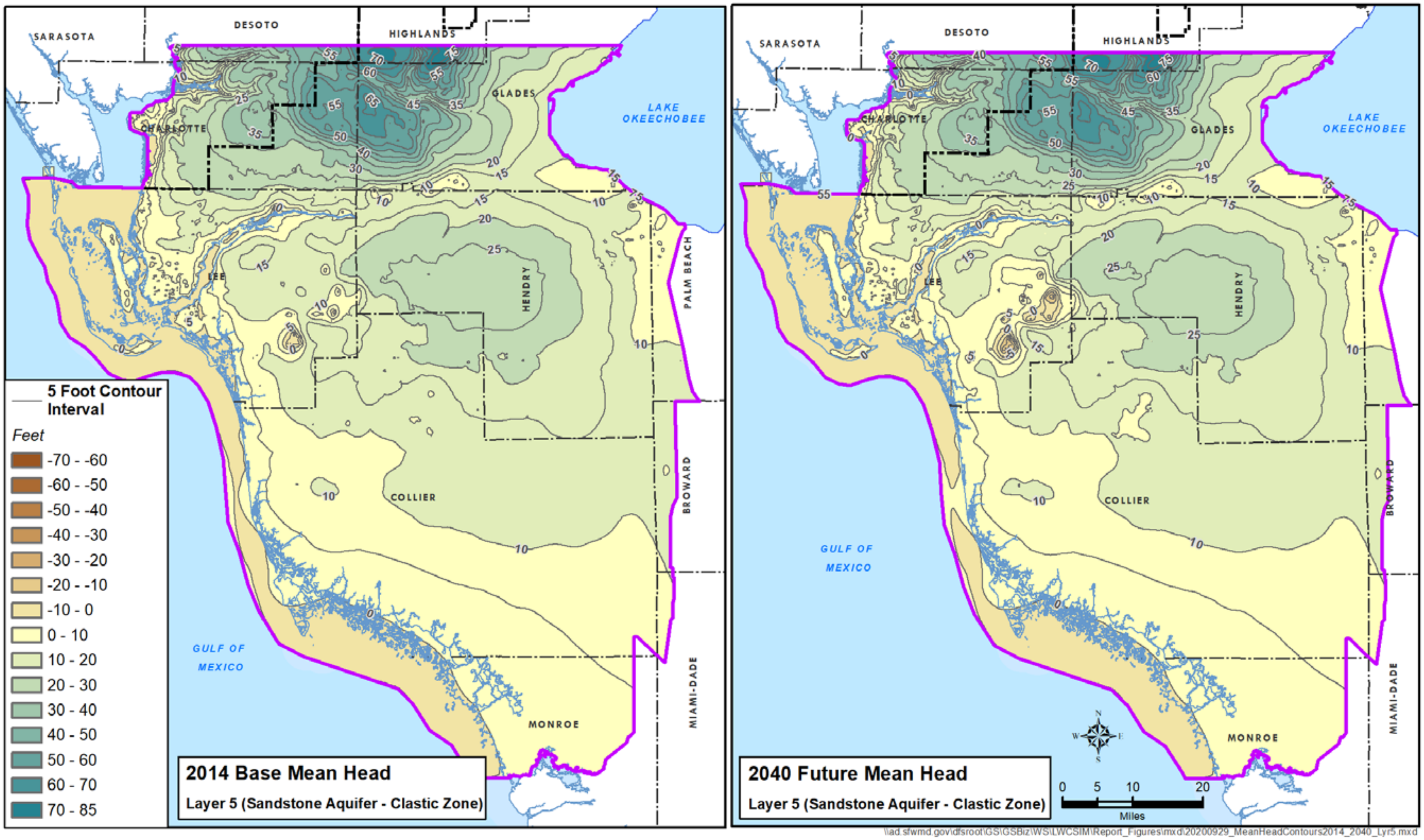

Figure 16. 2014 and 2040 mean heads in the Sandstone aquifer – clastic zone.

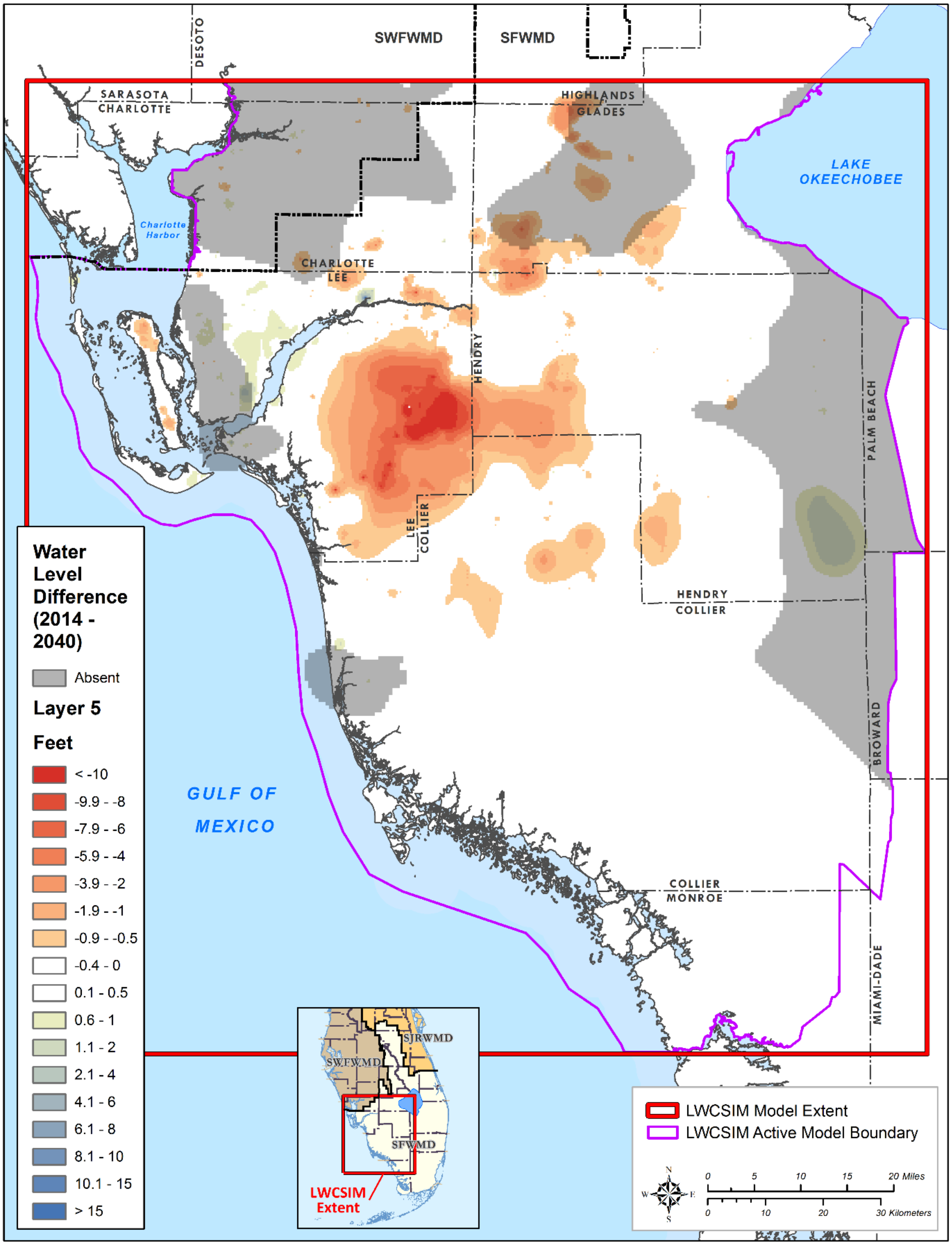

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Figure 17. 2014 to 2040 water level difference in the Sandstone aquifer – clastic zone.

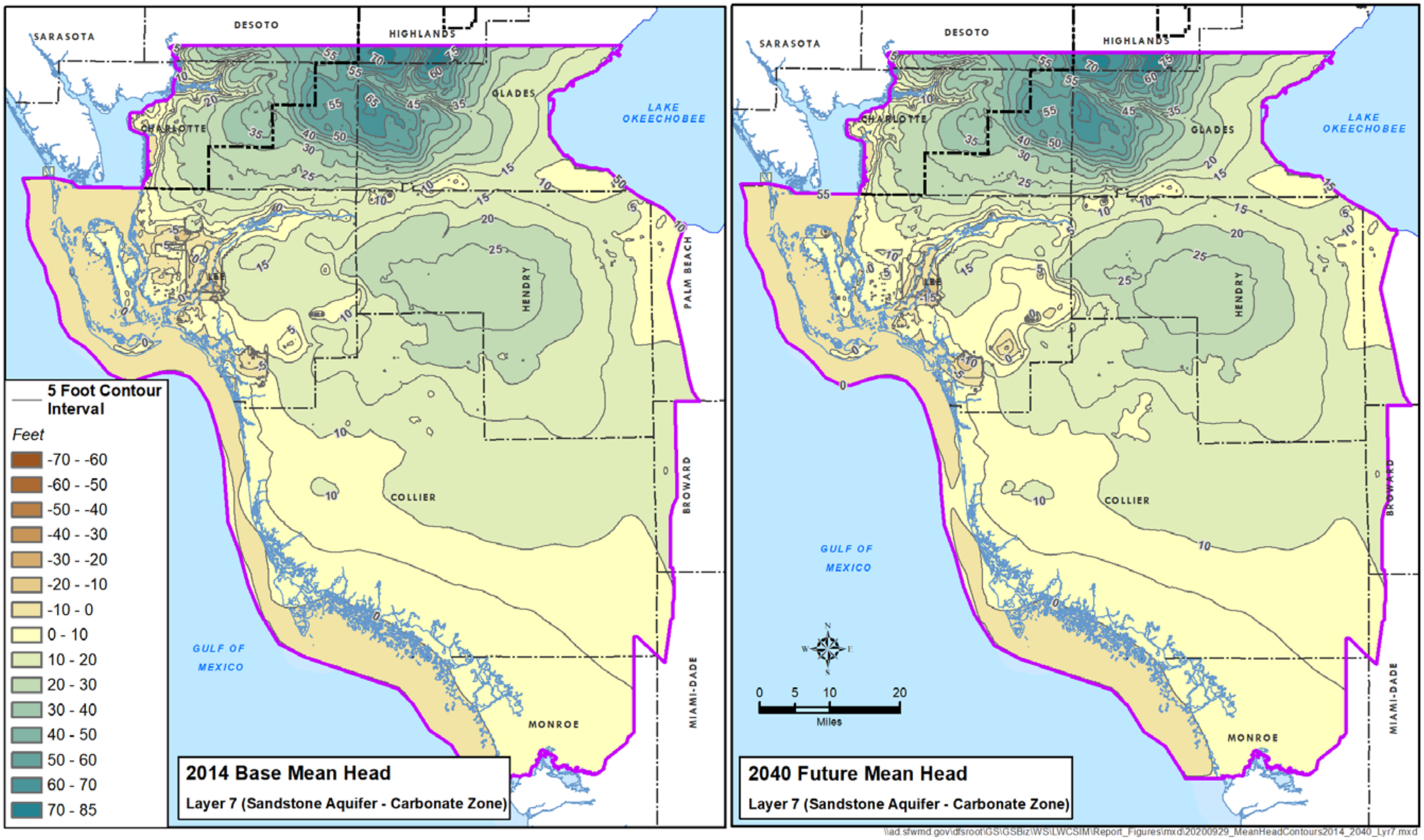

Figure 18. 2014 and 2040 mean heads in the Sandstone aquifer – carbonate zone.

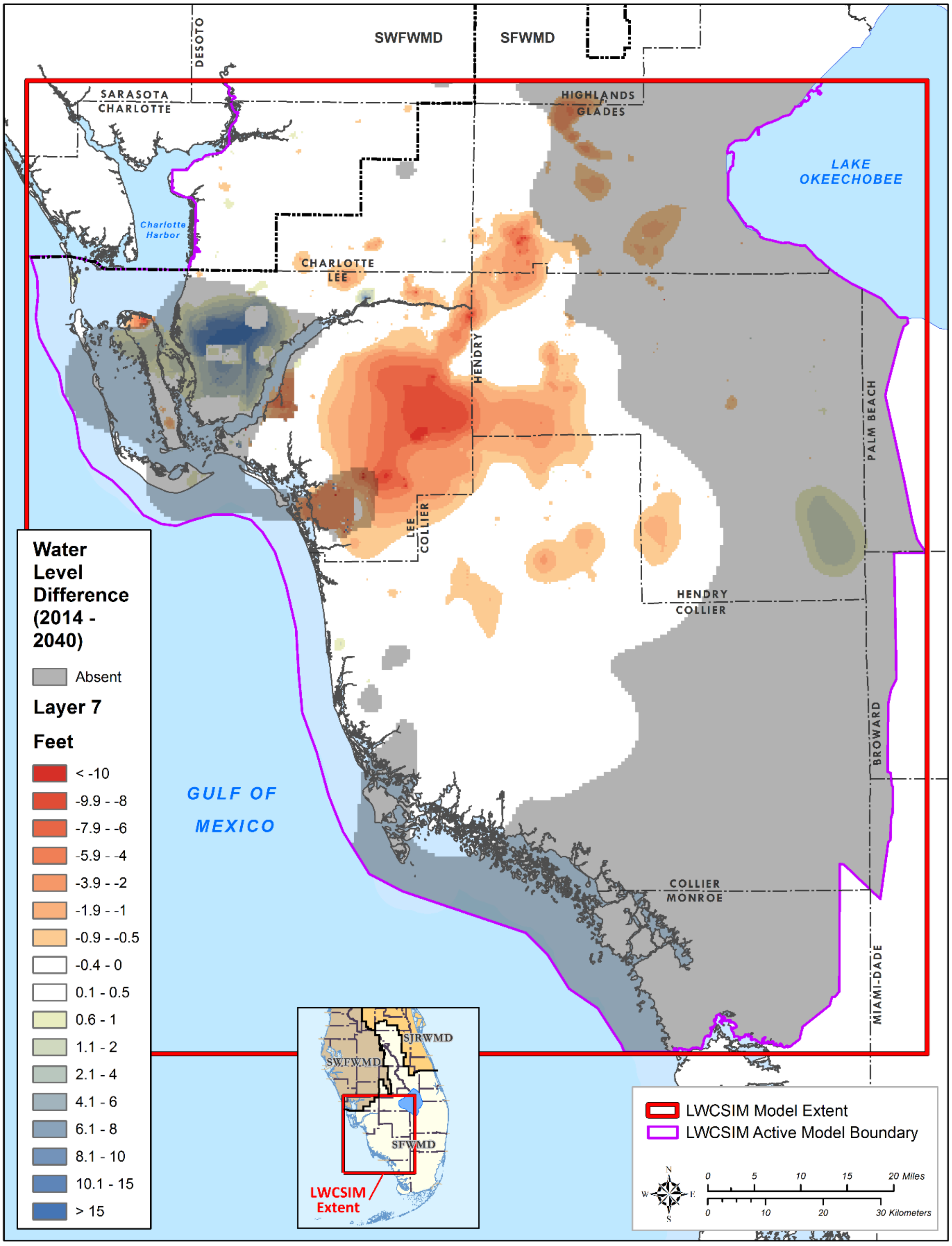

Figure 19. 2014 to 2040 water level difference in the Sandstone aquifer – carbonate zone.

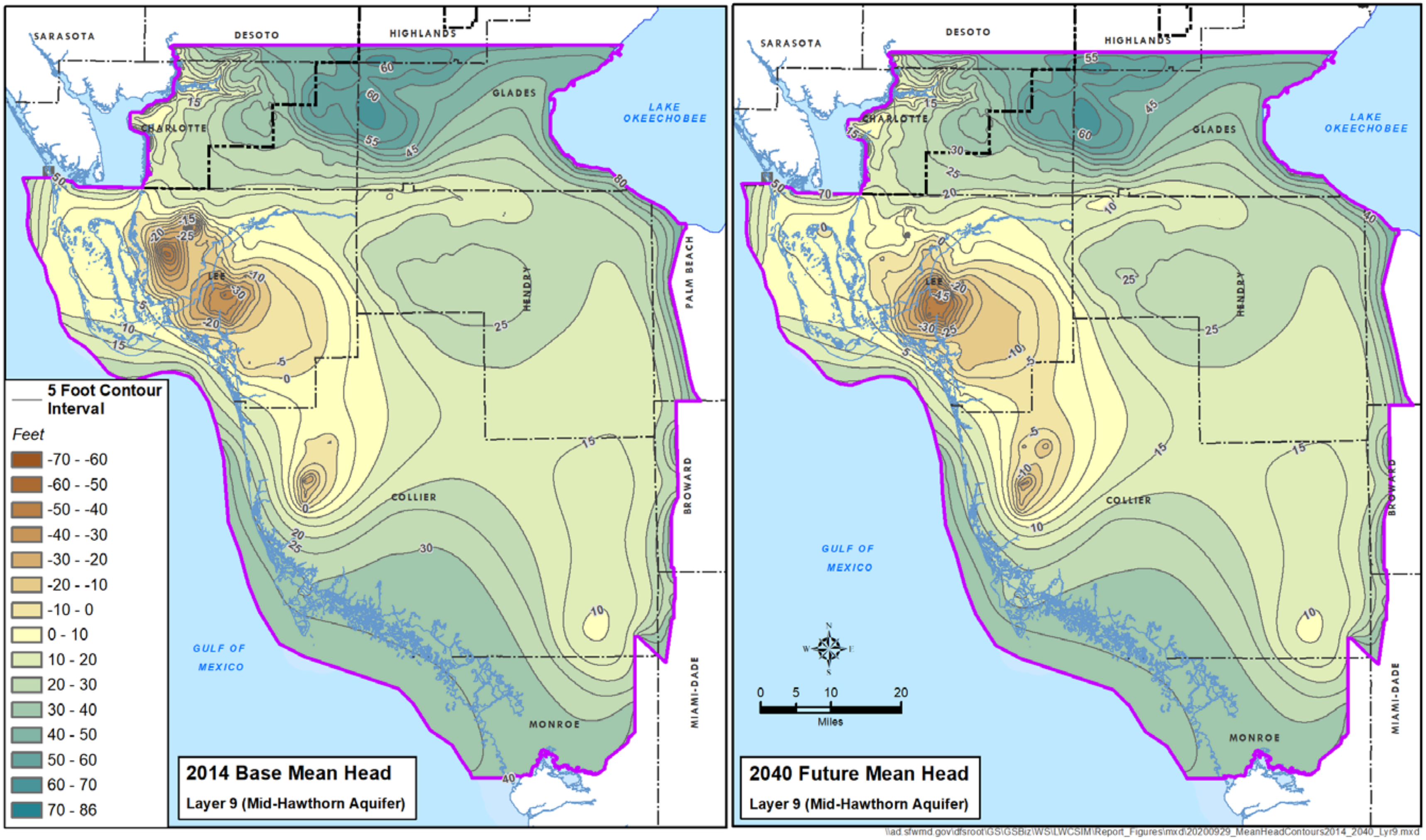

Figure 20. 2014 and 2040 mean heads in the Mid-Hawthorn aquifer.

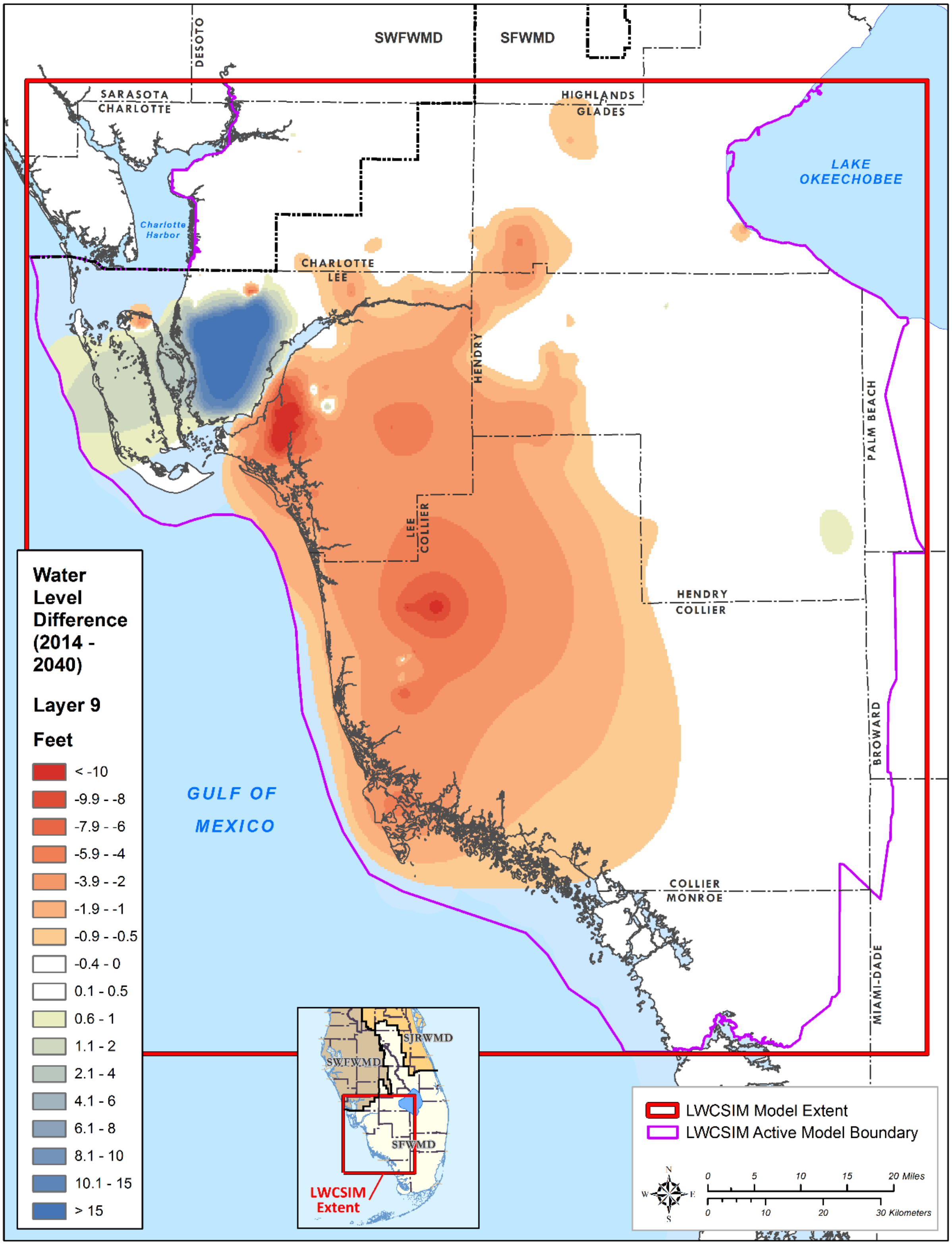

Figure 21. 2014 to 2040 water level difference in the Mid-Hawthorn aquifer.

Potential Effects of Pumping on Wetlands

The goal of the wetland impact analysis was to identify wetland areas that warrant further investigation and evaluation under 2040 projected pumping conditions. The screening criterion to identify potentially impacted areas was any wetland area with 1 foot or greater of additional drawdown in the WTA in 2040. The procedure was as follows:

1. Turn off pumps and return flows, then conduct the 2014 run.
2. Take the head difference between the run in step 1 and the 2014 run with pumps on.
3. Turn off pumps and return flows, then conduct the 2040 run.
4. Take the head difference between the run in step 3 and the 2040 run with pumps on.
5. Determine the head difference between steps 2 and 4.
6. Map areas with 1 foot or more of drawdown.
7. Map areas that rebounded to less than 1 foot of drawdown (improved).

Figure 22 illustrates the wetland areas potentially impacted by increased cumulative withdrawals in 2040. There are areas of measurable water level change in the WTA that correspond to mapped wetlands. After running the simulations and comparing the results, the areas of water level change in the WTA were laid over the current mapped wetland areas to determine the wetland areas potentially under the influence of changing well withdrawals. In **Figure 22**, wetlands in an area of 1 foot or more drop in water level due to a change in pumping are shown in red, and wetlands in areas that rebounded to less than 1 foot of drawdown are shown in blue. Wetlands from the 2014 land use/land cover map are shown in light green.

It is important to note that this exercise was an attempt to isolate the potential impacts of changing groundwater withdrawals on wetland systems. The LWCSIM was calibrated to boundary conditions with pumping occurring, not to the extreme condition of no pumping. The effects of drainage and development (i.e., changes in land use over time), which can be significant, were not considered as they are outside the model scope.

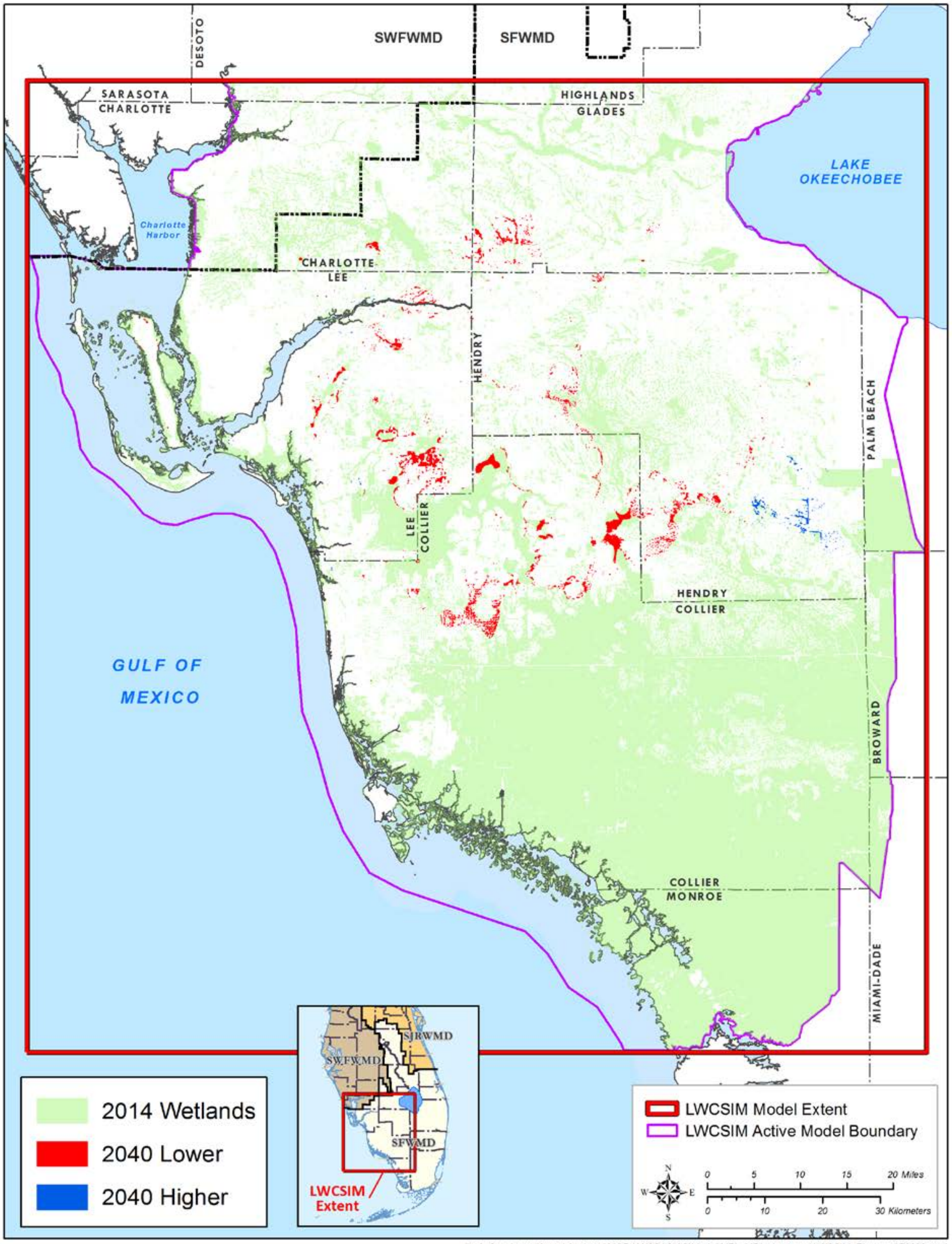

Figure 22. Wetlands potentially affected by projected pumping in 2040.

Maximum Developable Limits Analyses

In 2003, the SFWMD adopted MDL rules requiring permitted well withdrawals not cause harmful drawdown that will mine (or overdraw) semi-confined freshwater aquifers within the LWC Planning Area (SFWMD 2010). The Maximum Developable Limit (MDL) is defined as follows:

> *The potentiometric head within the Lower Tamiami aquifer, Sandstone aquifer, and Mid-Hawthorn aquifer shall not be allowed to drop to less than 20 feet above the top of the uppermost geologic strata that comprises the aquifer at any point during a 1-in-10 drought condition. This criteria must be met except in areas closer than 50 feet from any existing pumping well.*

MDLs represent a key prevention strategy for keeping aquifer water levels compliant with the Minimum Flow and Minimum Water Levels (MFLs) established for the LTA, SSA, and MHA (Rules 40E-8.231 and 8.331, Florida Administrative Code). **Figure 23** illustrates the MDL concept using the SSA.

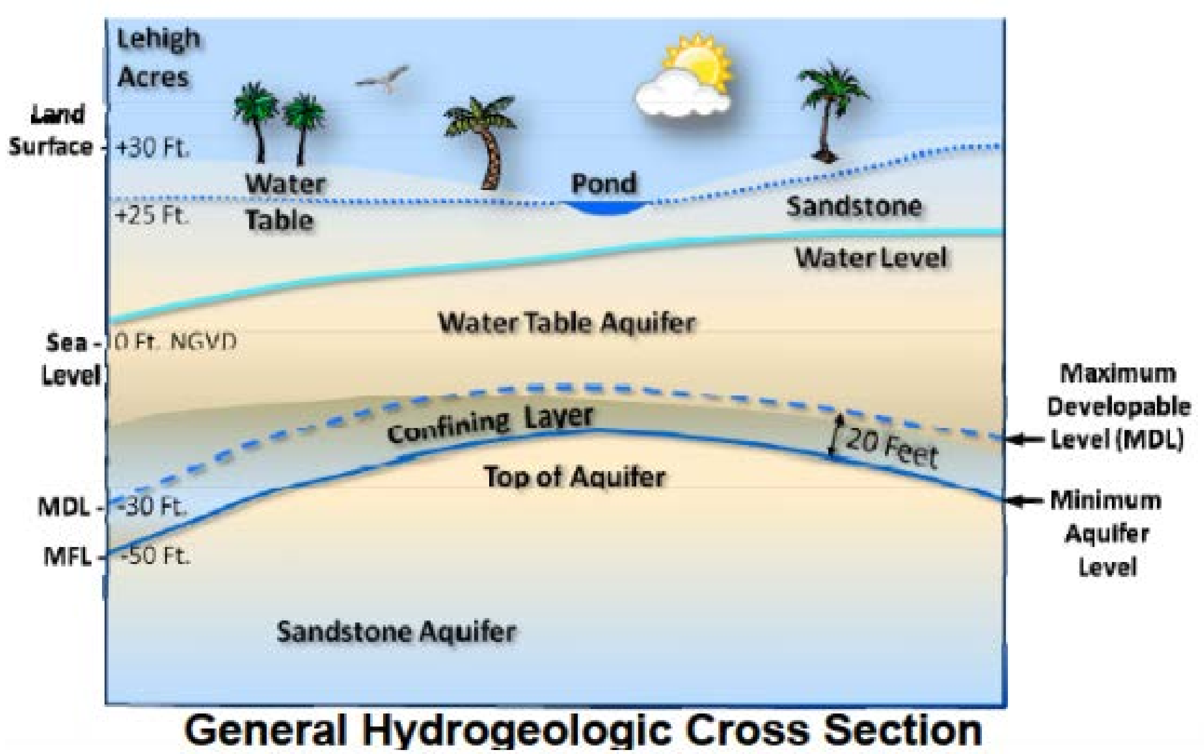

Figure 23. Illustration of Maximum Developable Limit concept.

MDL potentiometric head surfaces were developed from the 2014 reference condition for the LTA, SSA, and MHA. A 1-in-10 year drought was determined based on rainfall data from 1965 through 2013. An annual rainfall of 45 inches was determined to be the 1-in-10 year drought rainfall amount in the LWC Planning Area based on the probability exceedance curve (**Figure 24**). Within the transient model period of record, 2007 had the closest rainfall amount (43 inches) to the 1-in-10 year drought condition. Although 2007 was slightly drier than a 1-in-10 year drought condition, it was selected as a conservative option for MDL analysis. Specifically, May 2007 was chosen as the stress period from which to extract potentiometric heads for generating the MDL surface, as May represents the end of the dry season (**Figure 24**).

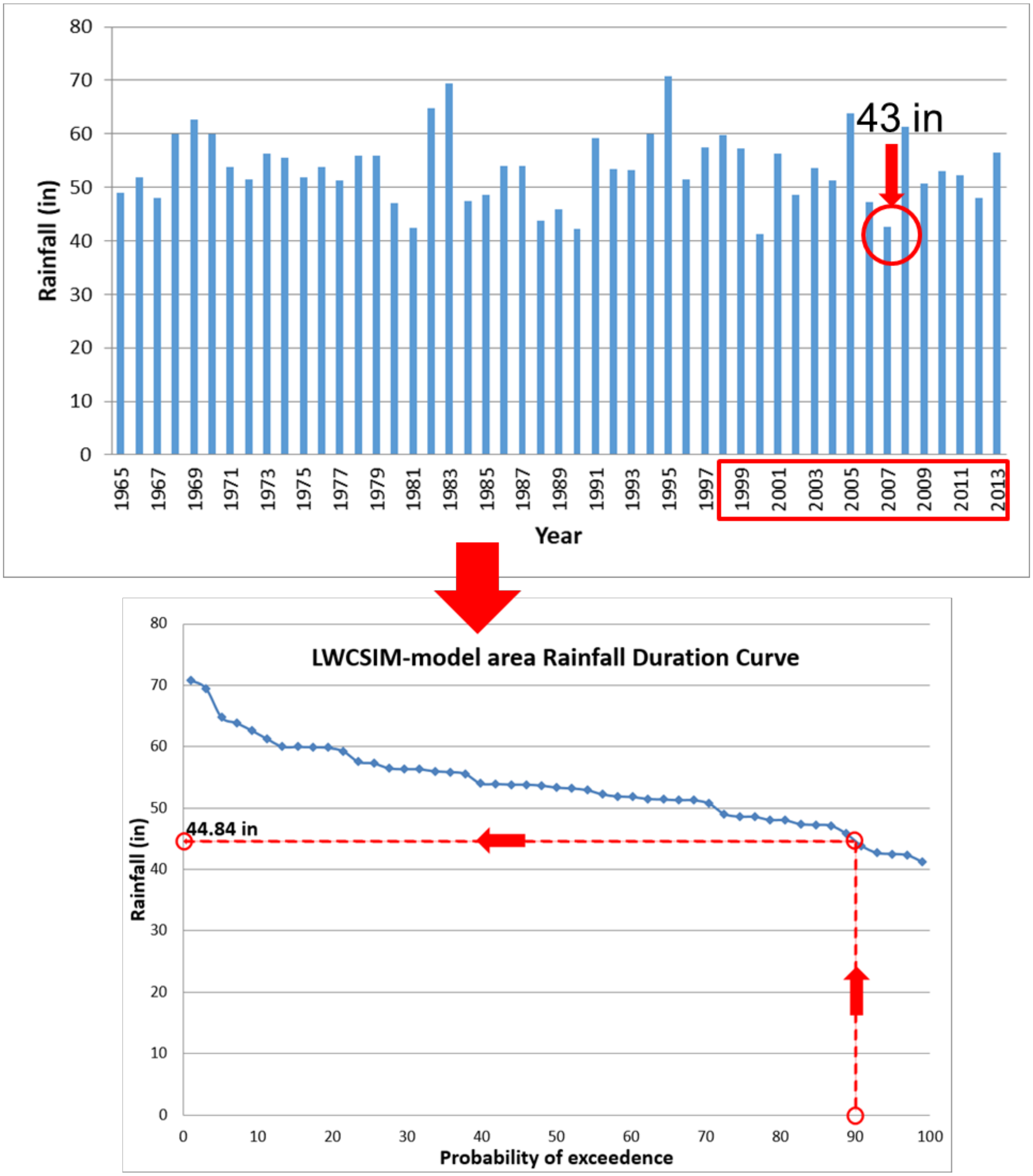

Figure 24. Selection of a 1-in-10 drought year.

The LTA showed areas of possible concern for the MDL, particularly along the boundary of Collier and Hendry counties near the center of the LWCSIM domain. There are possible MDL violations in the LTA near the Gator Slough, Highlands Citrus, Coop Three, Corkscrew Grove, and Coral Creek Grove agricultural permit areas (**Figure 25**). In the SSA-clastic, there was a small area of interest near Highlands Citrus (**Figure 26**). The MHA showed no potential MDL violations.

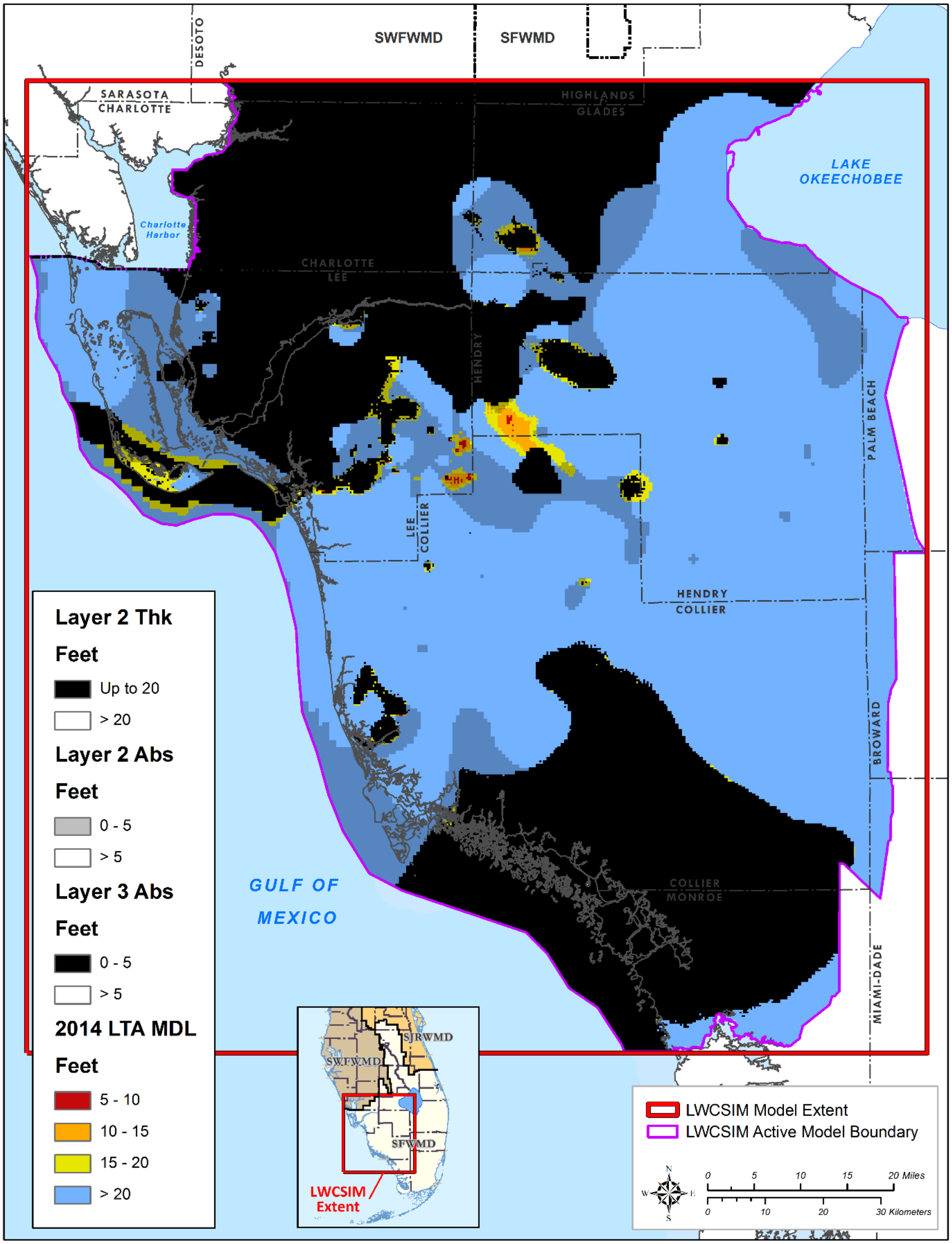

Figure 25. Simulated Maximum Developable Limit surface for the Lower Tamiami aquifer.

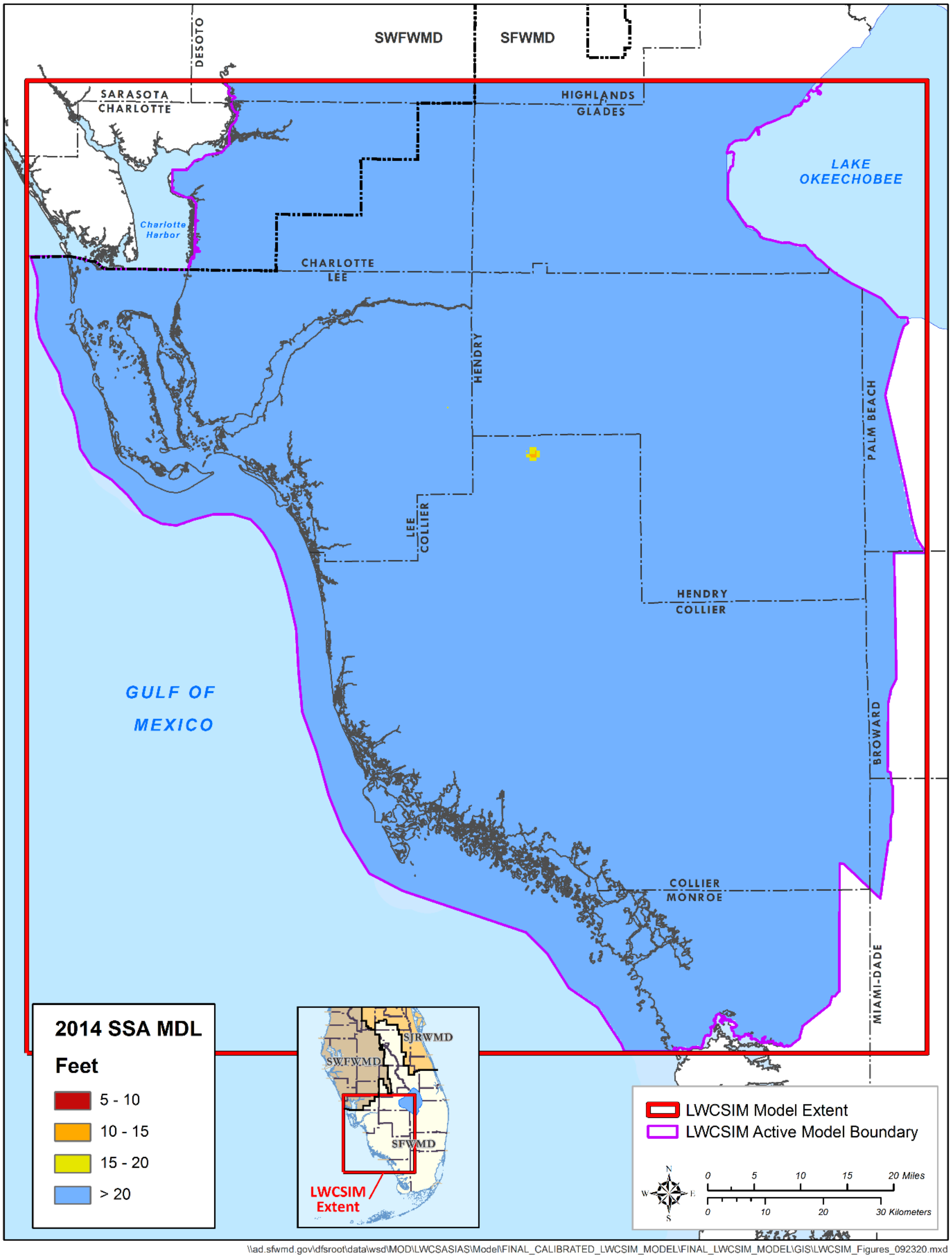

Figure 26. Simulated Maximum Developable Limit surface for the Sandstone aquifer.

Potentially impacted areas in the LTA are in an area of the LWCSIM domain where there is no tight confinement between the LTA and overlying WTA. Defining the aquifer being used in that area is difficult, which makes defining an accurate MDL challenging. Also, reported monitor well water level data at the permit locations indicate there historically have been no MDL violations in the area. Furthermore, the modeled AG demands were estimated using AFSIRS (due to the absence of metered data) and adjusted to achieve better calibration. Actual water use withdrawals may differ from those simulated by the AFSIRS program, which may account for the simulated MDL exceedances when none have been observed in measured water levels. There is no significant confinement between the SSA and overlying LTA near the potential MDL violation area in the SSA. There are several agricultural permits in this area; however, the groundwater demands from these permits are projected to decline over the planning horizon, and the potential for future violation of the MDL due to pumping is low.

Velocity Vectors Around Public Supply Wellfields

The LWCSIM simulates groundwater flow but is not capable of simulating solute transport (i.e., it is not a density-dependent model). Therefore, the LWCSIM cannot explicitly simulate intrusion of denser saltwater into freshwater portions of aquifer. However, groundwater flow vectors (or velocity vectors) can be an indication of the direction of movement of the saltwater-freshwater interface, which could be used to identify any increased threat of lateral saltwater intrusion under the influence of the projected water demand increases.

The flow of groundwater under a regional groundwater gradient and in the vicinity of pumping wellfields can be graphically represented for each aquifer using groundwater velocity vectors. In the LWCSIM, velocity was determined from cell-by-cell flows. There are two x-direction flows (horizontal within aquifer) and two y-direction flows (vertical between aquifers) per model cell. These were averaged in the x and y directions after dividing by the cross-sectional area normal to the cell face. These cell average velocity values were divided by porosity, yielding a groundwater flow or seepage velocity in units of feet per day. The vector was drawn based on the horizontal and vertical velocity components. If there was a net upward component of flow, the vector was colored blue; if there was a net downward component, the vector was colored red. Velocity vector arrows were drawn proportional to the magnitude of the seepage velocity. For example, seepage velocities in the LTA in the 2014 scenario ranged from 0 to 5 feet/day, with an average of 0.29 feet/day.

Figure 27 shows the major PS permits near the mapped saltwater interfaces along the Gulf coast (SFWMD in prep.). The SFWMD developed saltwater interface maps for coastal aquifers in the area in 2009, 2014, and 2019. These maps are available at https://www.sfwmd.gov/documents-by-tag/saltwaterinterface.

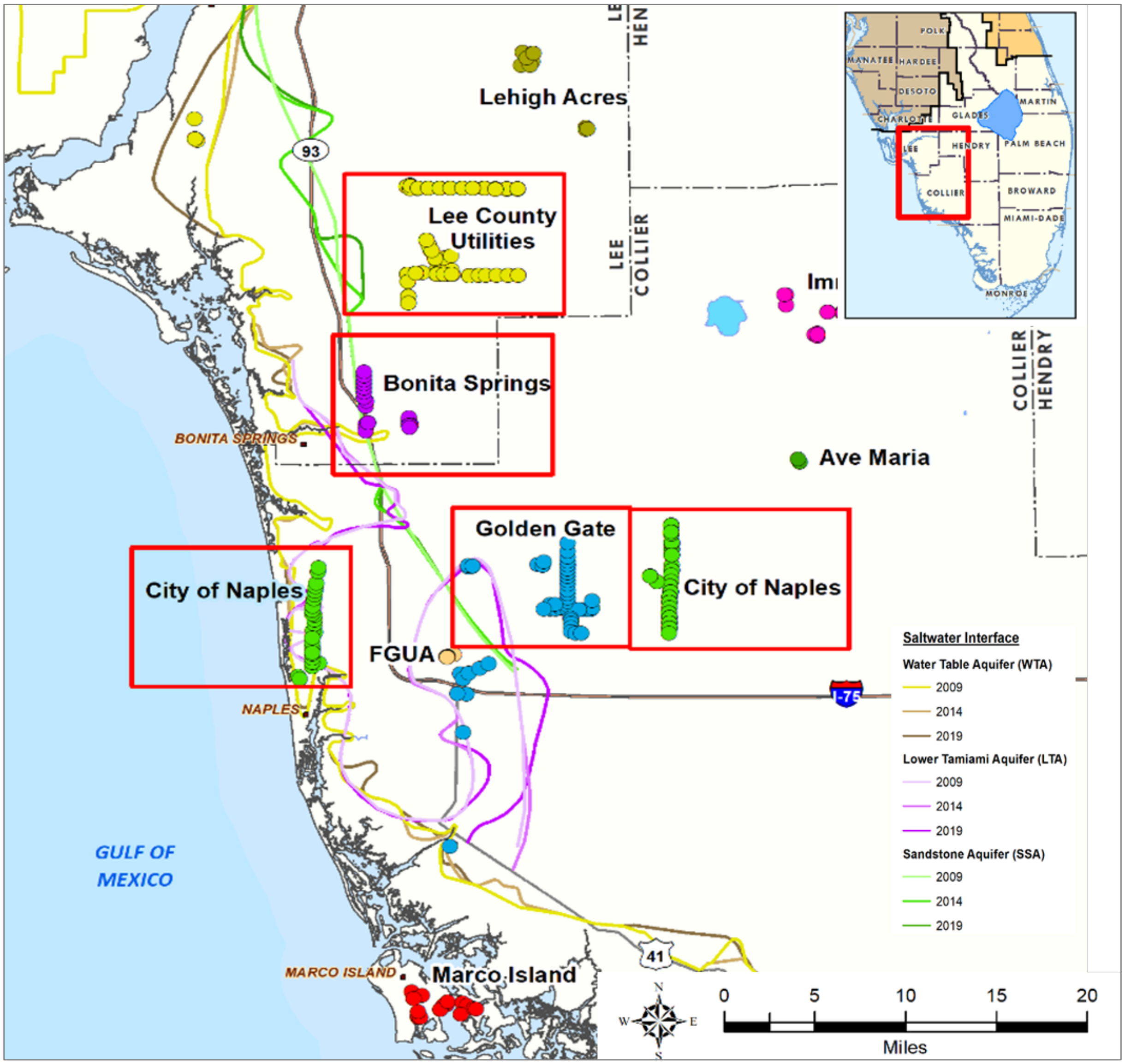

Figure 27. Major Public Supply permits in proximity to the saltwater interface.

Velocity Vectors and the Saltwater Interface

Velocity vectors were generated from the 2014 and 2040 scenarios to illustrate the groundwater flow field around major PS pumping wellfields close to the Gulf coast and, therefore, adjacent to the saltwater interfaces in the WTA, LTA, and SSA. Saltwater interfaces represent 250 milligrams per liter (mg/L) chloride isochlors. **Figures 28** to **32** illustrate how groundwater moves near major PS wellfields and the mapped saltwater interfaces.

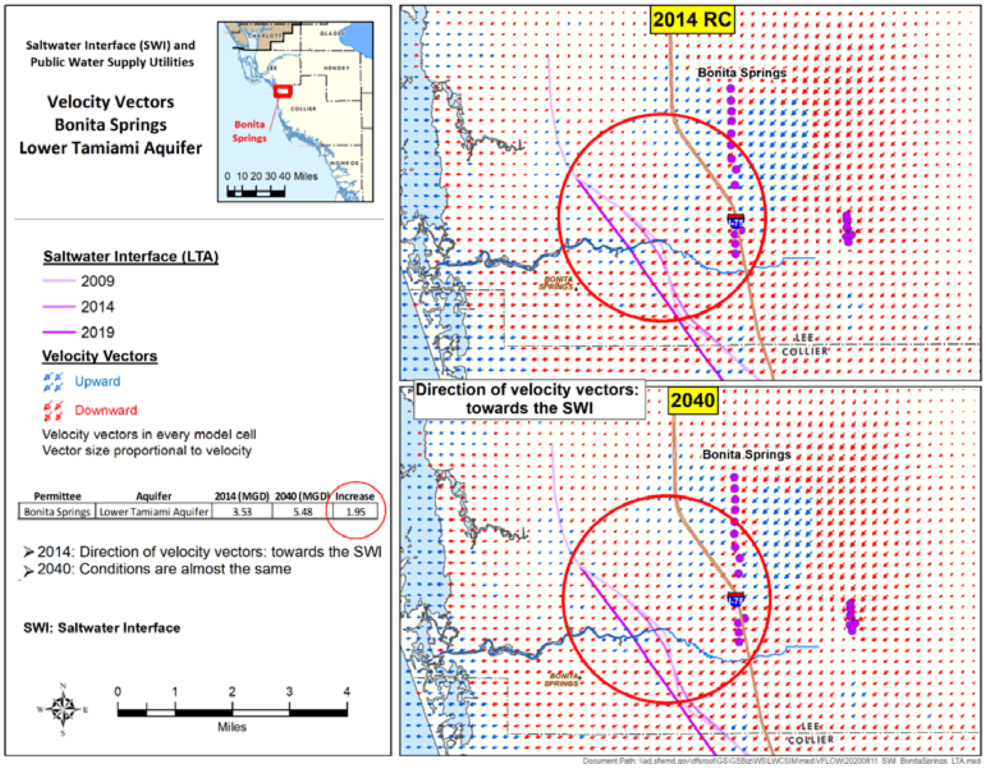

Figure 28. Velocity vectors (magnitude in feet/day) in the Lower Tamiami aquifer near the Bonita Springs wellfield.

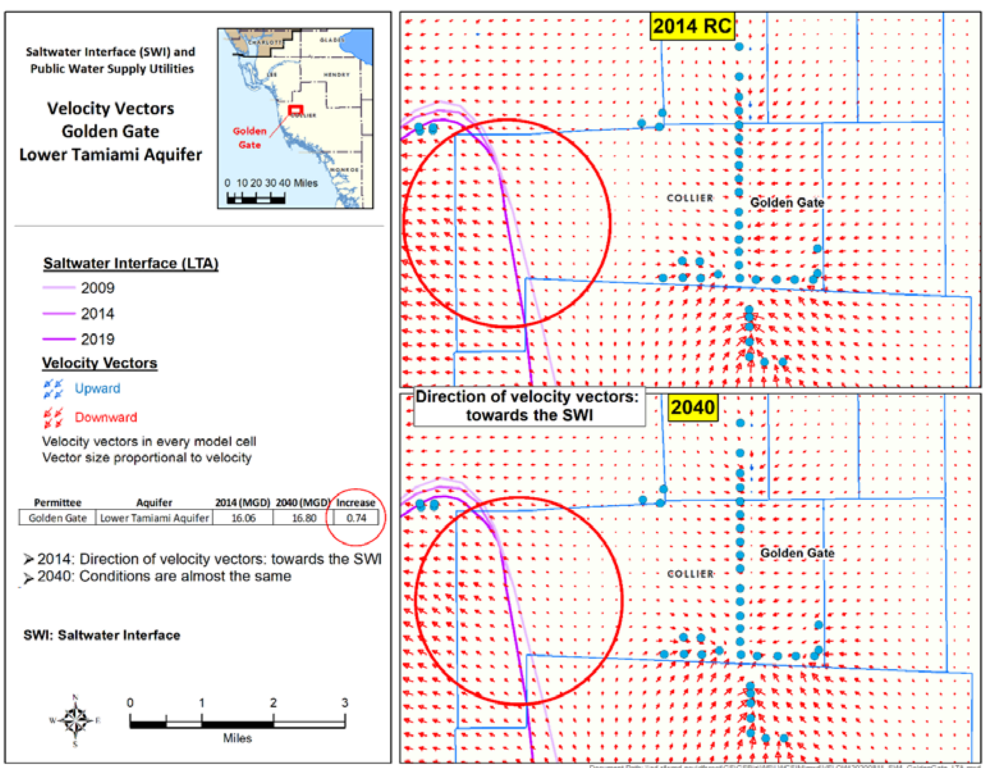

Figure 29. Velocity vectors (magnitude in feet/day) in the Lower Tamiami aquifer near the Golden Gate wellfield.

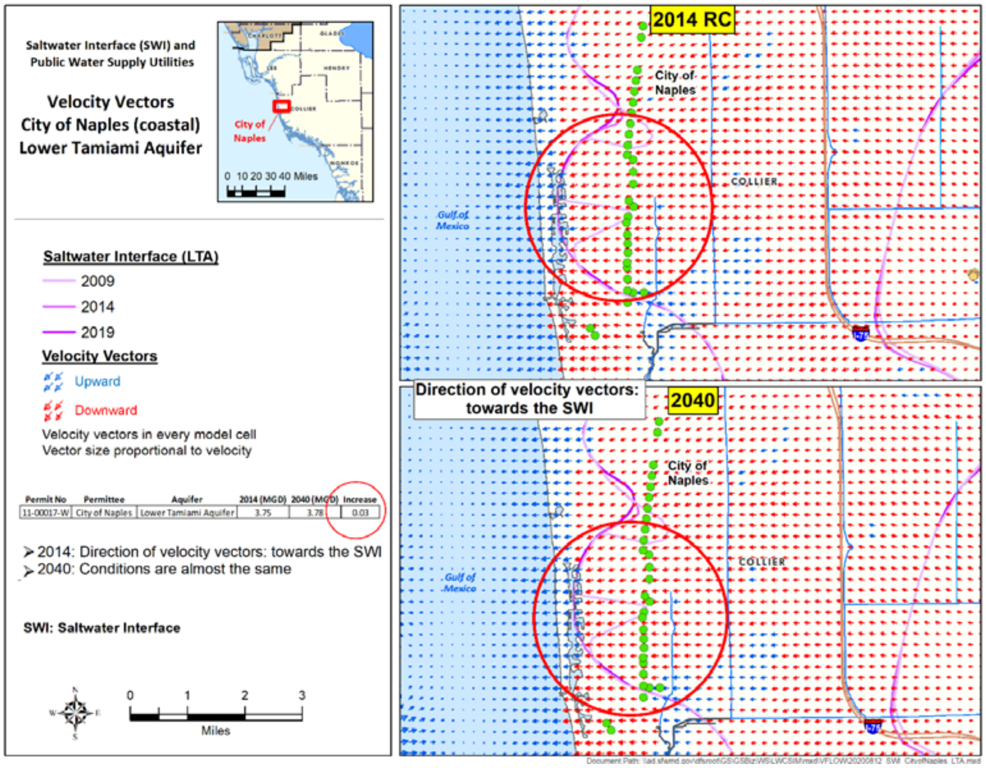

Figure 30. Velocity vectors (magnitude in feet/day) in the Lower Tamiami aquifer near the City of Naples (coastal) wellfield.

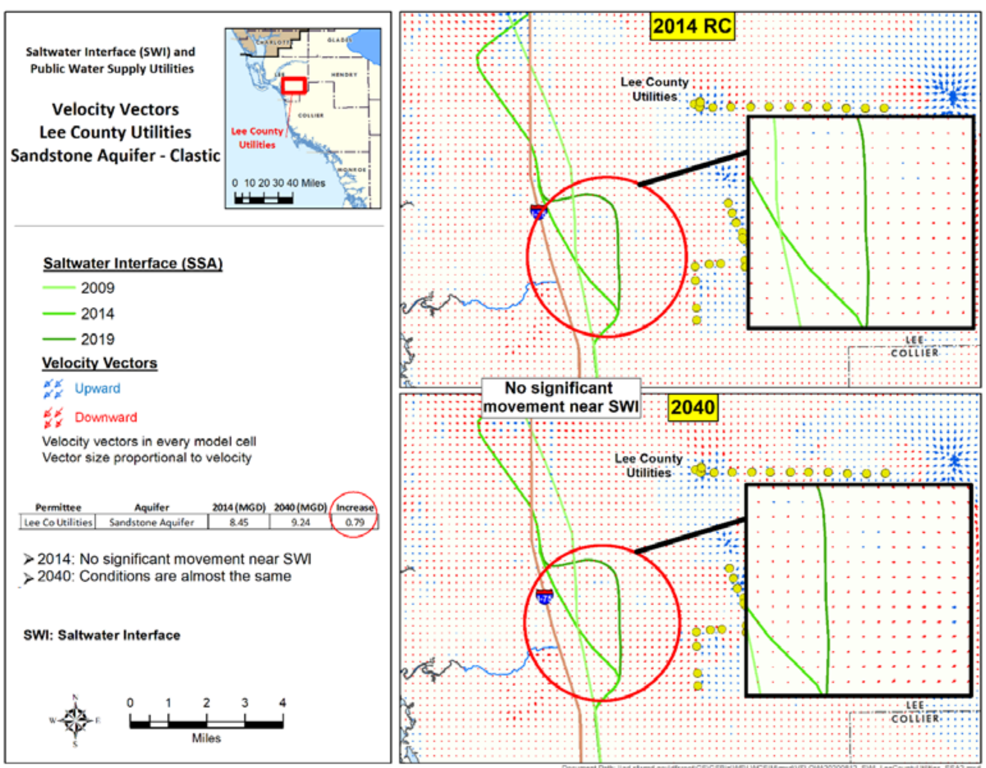

Figure 31. Velocity vectors (magnitude in feet/day) in the Sandstone aquifer – clastic zone near the Lee County Utilities wellfield.

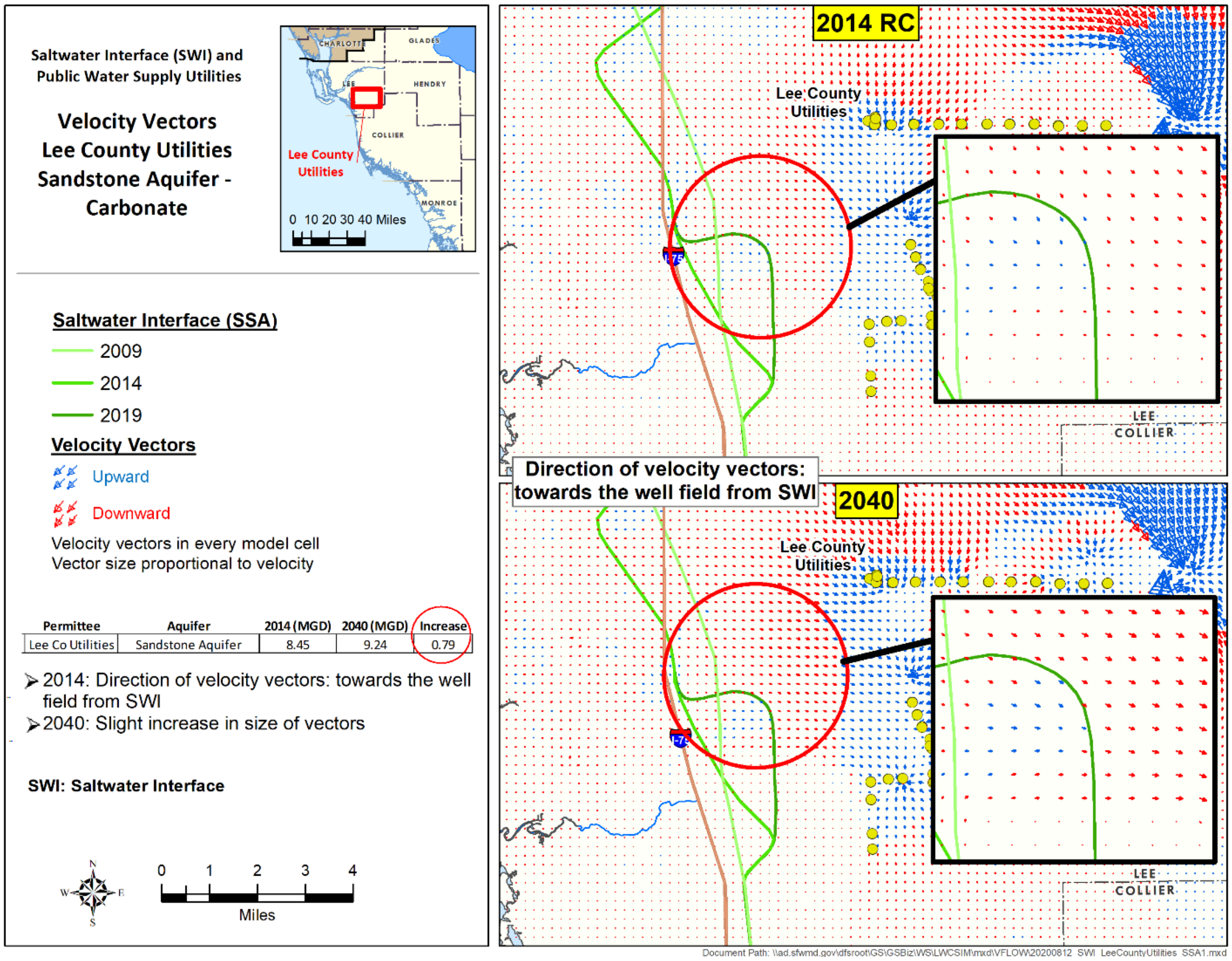

Figure 32. Velocity vectors (magnitude in feet/day) in the Sandstone aquifer – carbonate zone near the Lee County Utilities wellfield.

Figures 28 to **31** illustrate that, in the cases of Bonita Springs, City of Naples (coastal), and Golden Gate—all in the LTA—and Lee County Utilities in the SSA-clastic, groundwater flow is generally towards the saltwater interface and does not change between 2014 and 2040. The velocity vectors generally are small and indicate groundwater movement under the regional flow gradient that is not significantly perturbed near the saltwater interface. In other words, for the Bonita Springs, City of Naples (coastal), and Golden Gate permits, the modest increases in projected PS withdrawals do not significantly influence the normal regional flow of groundwater near the saltwater interface. However, for Lee County Utilities in the SSA-carbonate, there is some indication of groundwater velocity vectors turning slightly towards the wellfield and away from the saltwater interface (**Figure 32**). The groundwater flow velocities are small (small vector arrows) and the influence of the pumping wells is not significant; however, there appears to be some influence exerted by the wellfield beyond the expected influence very near the pumping wells. Also, a slight increase in the size of the vectors in 2040 indicates increased flow towards the wellfield due to a proposed increase in demand (0.79 mgd).

CONCLUSIONS

The LWCSIM was used to simulate 2014 reference condition and 2040 future scenario demands. AG and CII demands in the LWC Planning Area are projected to remain fairly constant, with only a slight (9%) increase in AG demands, primarily in Lee and Glades counties. DSS, PS, and L/R, however, have projected increases of 29%, 26%, and 47%, respectively. Overall, SAS/IAS demands in the LWC Planning Area are projected to increase approximately 19%, from 547 to 651 mgd (**Table 5**).

Table 5. Water use demands in the Lower West Coast Planning Area.

Demand Type	2014 (mgd)	2040 (mgd)	Difference (mgd)	% Increase
AG	344	376	32	9%
CII	3	3	0	0%
DSS	42	54	12	29%
PS	68	86	18	26%
L/R	90	132	42	47%
Total	**547**	**651**	**104**	**19%**

mgd = million gallons per day.

Groundwater flow model simulations were conducted to evaluate changes in water levels and water movement as a result of the net increase in SAS/IAS demands. The primary findings include the following:

- Water Level Differences – The differences in potentiometric head in each aquifer between 2014 and 2040 clearly show areas where water levels are predicted to decrease or increase under the projected changes in demands. In general, as demands increase, there will be subtle declines in water levels (1 to 5 feet) in each aquifer. A few areas could experience declines between 5 and 10 feet. The most notable increase in potentiometric head (25 ft) was observed in the MHA around Cape Coral, where users are expected to switching from DSS wells to PS wells that utilizes Floridan aquifer in 2040.
- Potential Effects of Changing Demands on Wetlands – Increasing or decreasing future demands may slightly influence wetlands, particularly in areas already extensively used for groundwater extraction. The changes in groundwater drawdowns between the 2014 and 2040 scenarios indicate a potential for some localized impact to wetland areas (**Figure 22**). Some wetlands may experience an increase in areas that lie within 1 foot of additional drawdown (shown in red) while some may experience a decrease where the groundwater level is projected to rebound due to decreased withdrawals (shown in blue).
- Potential Areas of Interest with Respect to MDLs – The 2014 reference condition scenario was used to simulate an MDL surface for the LTA, SSA, and MHA. The simulated MDL for the LTA indicates agricultural permittees in northern Collier, southern Hendry, and eastern Lee counties should continue to closely monitor groundwater levels with respect to the MDL, particularly when approaching permit withdrawal limits. Similarly, in the SSA, there is a small area of potential concern in northern Collier County, which may require monitoring in the future. The simulated MDL for the MHA showed no areas of potential concern under projected 2040 pumping condition.
- Saltwater Intrusion Potential – Groundwater velocity vector analyses show that, in general, large PS wellfields (current and future) do not significantly influence groundwater flow except very near the pumping wells. With the exception of Lee County Utilities in the SSA-carbonate, groundwater flow generally follows the regional flow gradient and is not significantly influenced near the saltwater interfaces. Therefore, no significant increased potential for lateral saltwater intrusion was identified due to the projected pumping increase in 2040. This result is partly due to the modest increase in projected withdrawals around the wellfields of historical concern with respect to saltwater intrusion.

The LWCSIM results do not indicate any widespread impacts to the groundwater resources or the natural system from the projected 2040 SAS/IAS demands in the LWC Planning Area. However, there are a few localized areas where minor potential impacts to groundwater resources and wetlands may occur. These areas need continued monitoring, additional planning, and adaptive planning strategies, such as increasing spacing between pumping wells and rotating operations between pumping wells to best manage the resource.

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APPENDIX:
LWCSIM PUBLIC SUPPLY PERMITS

2014 Public Supply Demands			2040 Public Supply Demands			Difference (mgd)
Permit	Utility	Average (mgd)	Permit	Utility	Average (mgd)	
08-00047-W	Charlotte Corr. Inst.	0.10	08-00047-W	Charlotte Corr. Inst.	0.10	0.00
11-00013-W	Immokalee Water & Sewer	1.93	08-00122-W	Town & Country Util.	0.78	-1.15
11-00017-W	City of Naples	14.13	11-00013-W	Immokalee Water & Sewer	2.41	-11.72
11-00052-W	Pelican Bay	0.74	11-00017-W	City of Naples	20.22	19.48
11-00080-W	Marco Island	1.85	11-00052-W	Pelican Bay	0.74	-1.11
11-00148-W	FGUA	1.64	11-00080-W	Marco Island	3.62	1.98
11-00160-W	Everglades City	0.16	11-00160-W	Everglades City	0.27	0.11
11-00249-W	Collier County PWS	23.77	11-00249-W	Collier County PWS	25.80	2.03
11-00372-W	Port of the Islands	0.22	11-00372-W	Port of the Islands	0.25	0.03
11-00419-W	Orange Tree	0.42	11-00419-W	Orange Tree	0.87	0.45
11-02298-W	Ave Maria	0.30	11-02298-W	Ave Maria	2.01	1.71
22-00045-W	City of Moorehaven	0.50	22-00045-W	City of Moorehaven	0.66	0.16
26-00096-W	Port Labelle	0.54	26-00096-W	Port Labelle	0.53	-0.01
26-00105-W	City of LaBelle PWS	0.36	26-00105-W	City of LaBelle PWS	0.01	-0.35
36-00003-W	Lee County Util.	14.07	36-00003-W	Lee County Util.	16.57	2.50
36-00008-W	Bonita Springs	3.53	36-00008-W	Bonita Springs	5.48	1.95
36-00081-W	Pine Lakes Country Club	0.10	36-00081-W	Pine Lakes Country Club	0.10	0.00
36-00122-W	Pinewood PWS	1.76	36-00122-W	Pinewood PWS	1.80	0.04
36-00166-W	FGUA/Lehigh Acres	2.06	36-00166-W	FGUA/Lehigh Acres	3.46	1.40
36-00208-W	Citrus Park RV Resort	0.19	36-00208-W	Citrus Park RV Resort	0.24	0.05
	Total	**68.35**			**85.92**	**17.56**